SRBAVG Products Validation/Status

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SSAI

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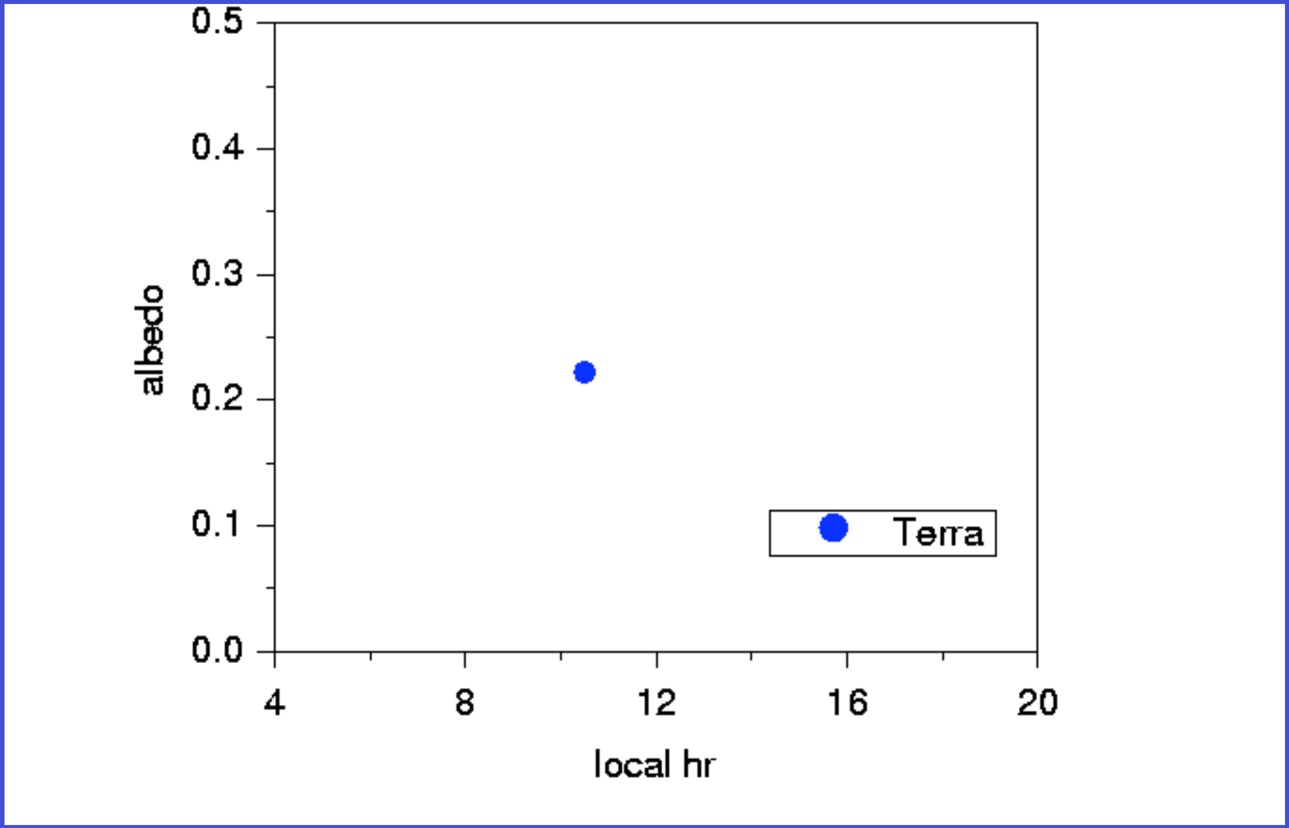
Outline

- CERES Temporal Interpolation between measurements
  - Adding in geostationary fluxes with CERES TOA fluxes completes the diurnal signal in the radiation budget
  - The CERES-GEO product fluxes are of climate quality
- CERES TOA gridded products
  - Review the globally gridded products
  - Order at http://eosweb.larc.nasa.gov/ under CERES
  - TOA annual mean global fluxes and net flux optimal closure
  - Archived products and production schedules
- Calculation of the incoming solar
  - Polar fluxes very sensitive to Ephemeris

Temporal Averaging

Convert instantaneous measured flux to daily mean flux

Example: Peruvian stratus region

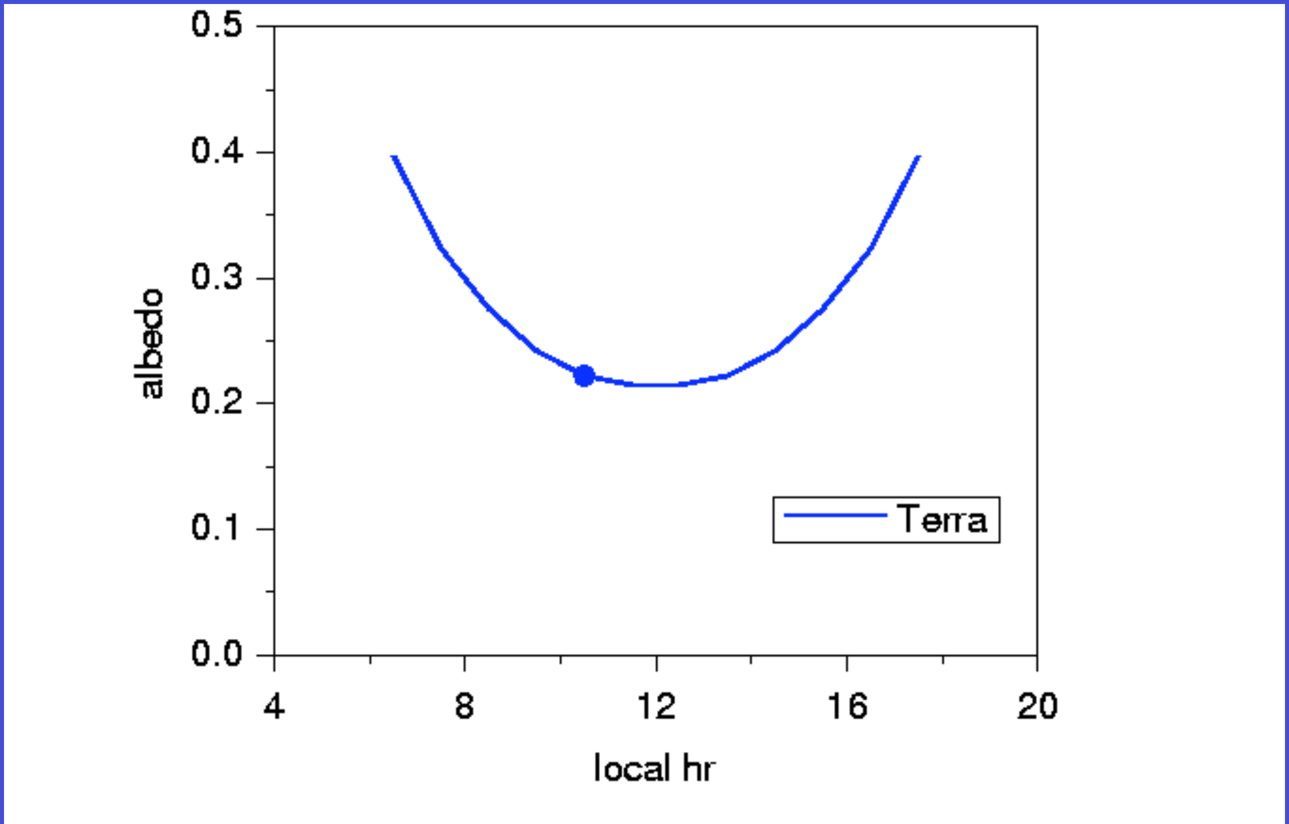


- Terra equatorial crossing time is 10:30AM
- Plot Terra albedo measurement

Temporal Averaging

Convert instantaneous measured flux to daily mean flux

Example: Peruvian stratus region

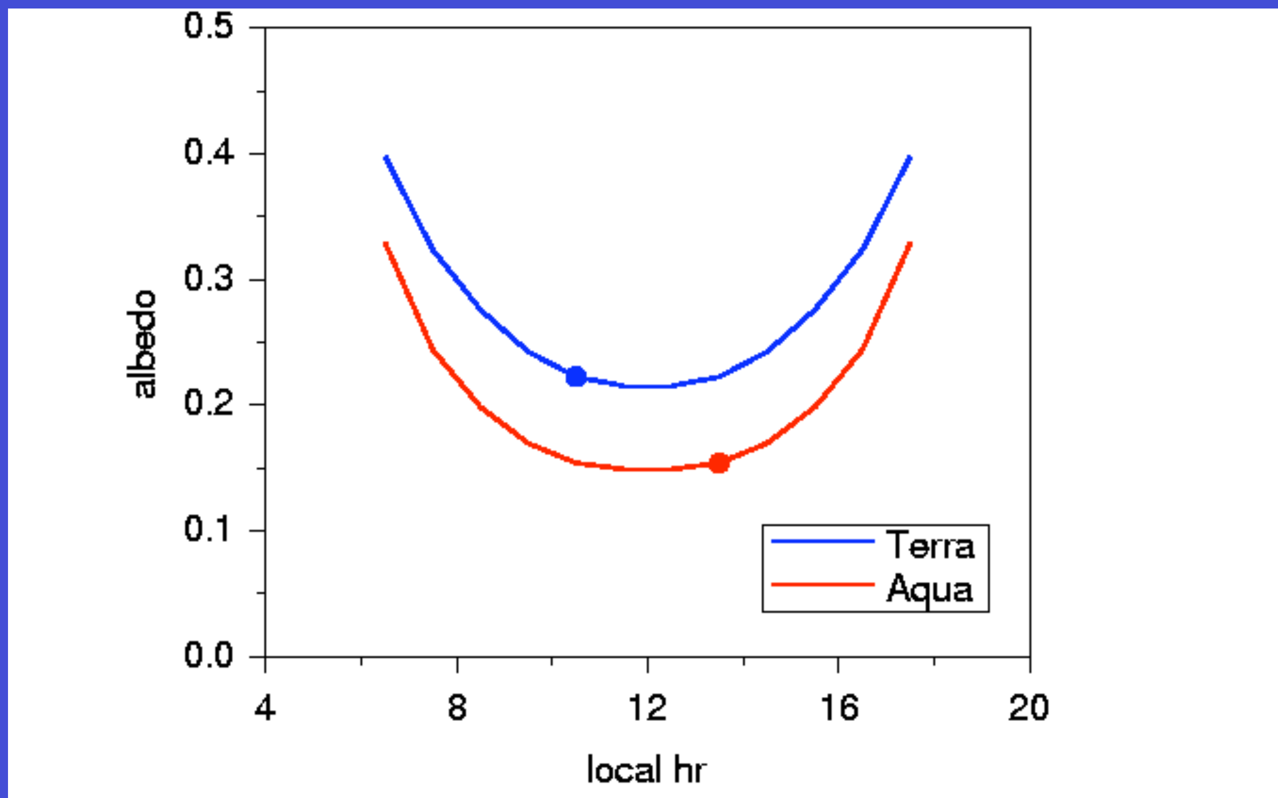


- Directional model relates albedo with solar zenith angle
- Assumes constant meteorology throughout the day

Temporal Averaging

Convert instantaneous measured flux to daily mean flux

Example: Peruvian stratus region

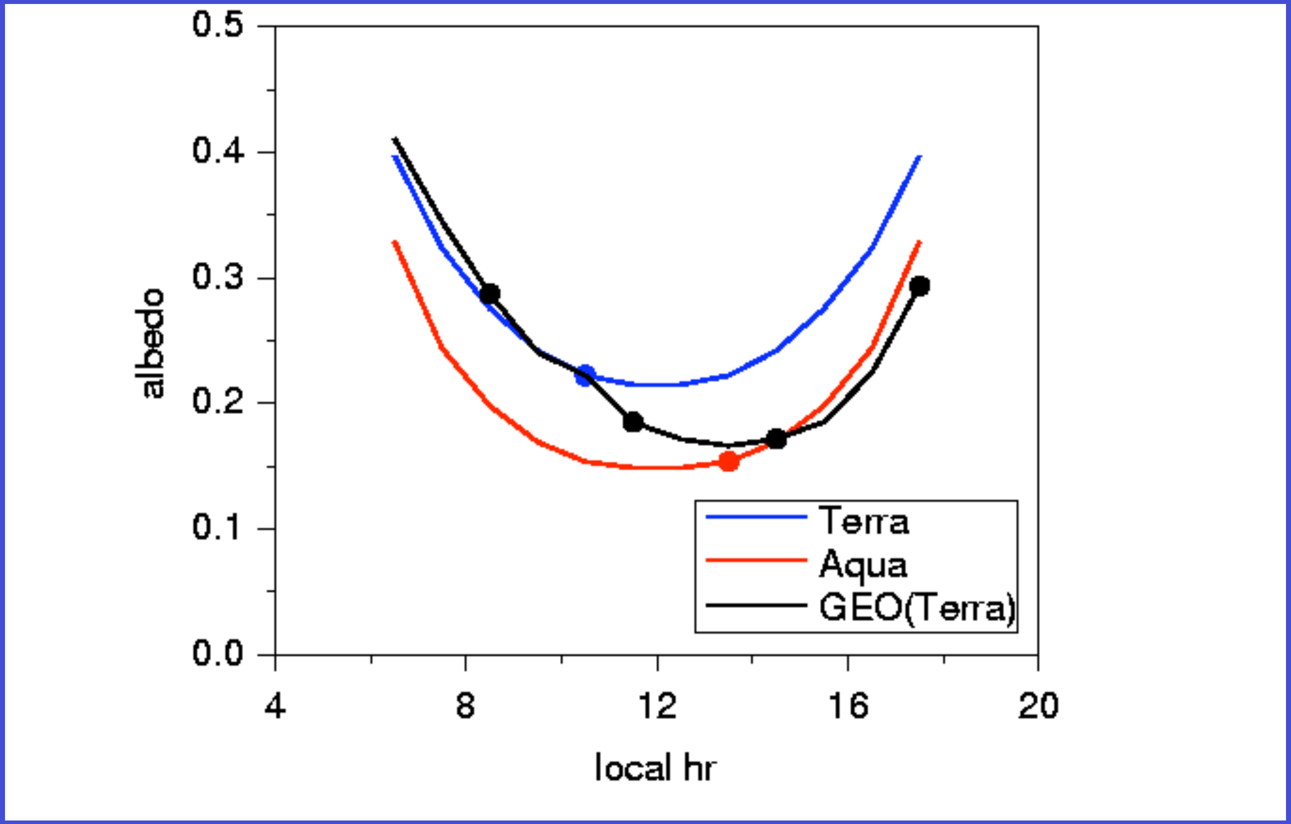


- Aqua equatorial crossing time is 1:30PM
- Cloud cover has decreased between Terra and Aqua measurement

Temporal Averaging

Convert instantaneous measured flux to daily mean flux

Example: Peruvian stratus region

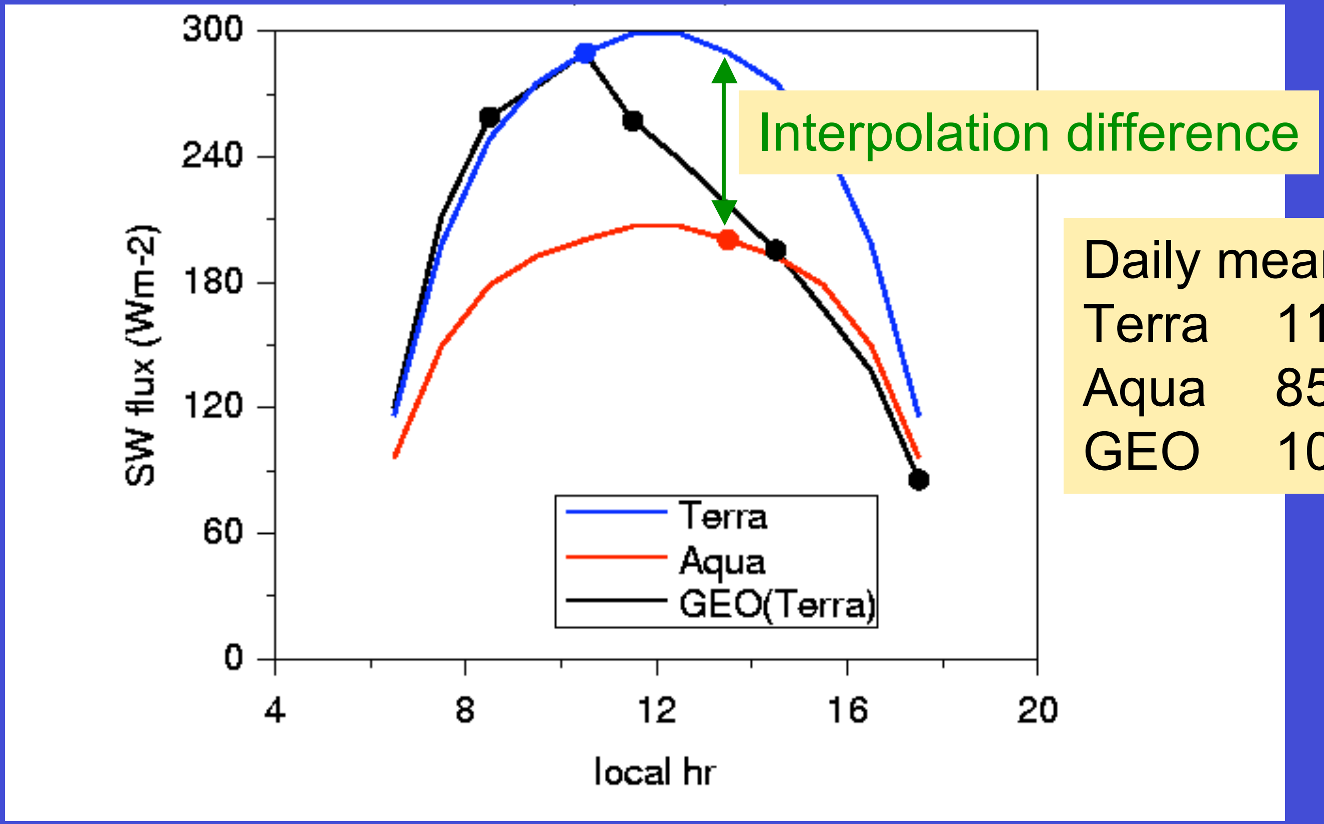


- Use geostationary 3-hourly derived albedos to resolve diurnal cycle

Temporal Averaging

Convert instantaneous measured flux to daily mean flux

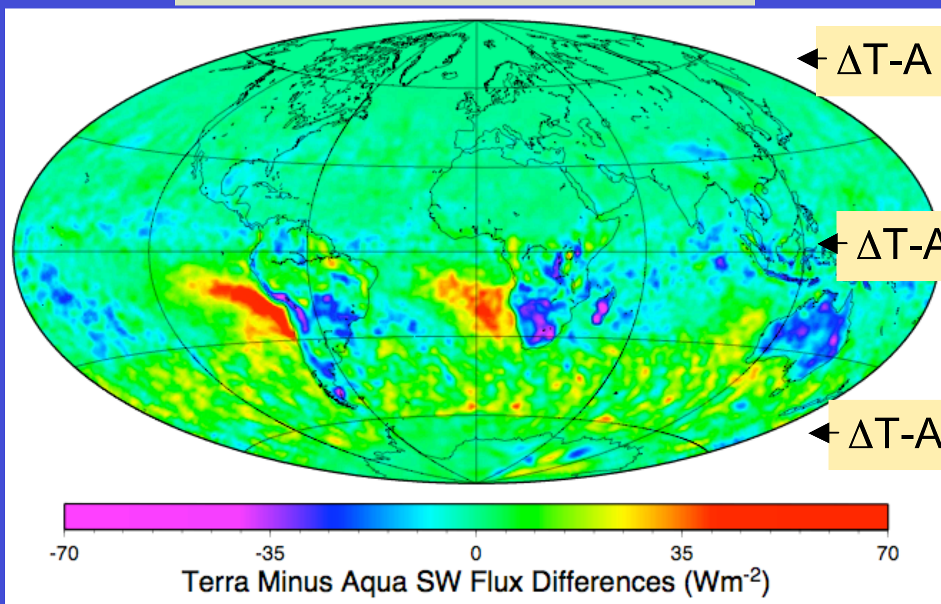
Example: Peruvian stratus region



Daily mean (Wm-2)	
Terra	119.0
Aqua	85.4
GEO	102.3

Terra (10:30 LT) - Aqua (1:30 LT) monthly CERES SW flux differences Dec 2002

CERES only fluxes

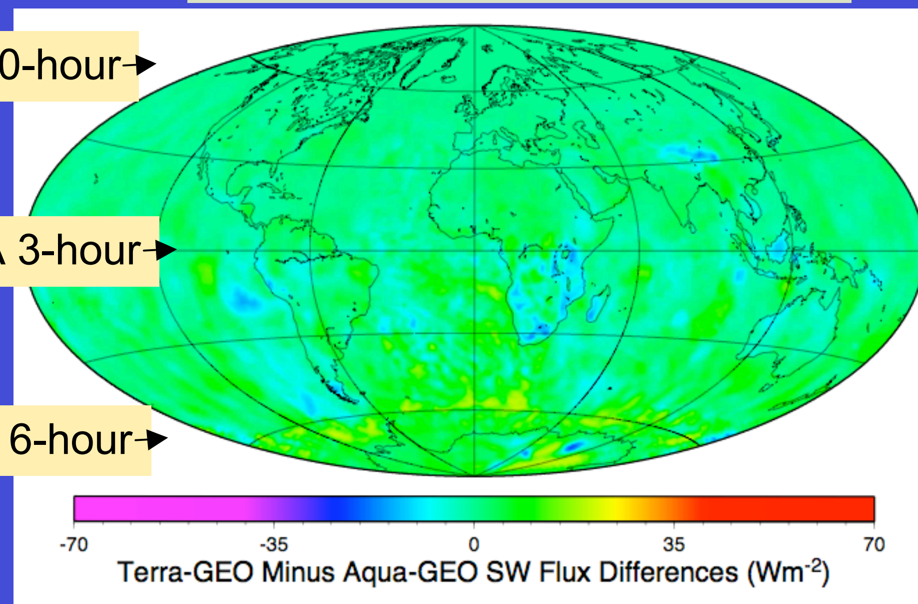


ΔT-A 0-hour

ΔT-A 3-hour

ΔT-A 6-hour

CERES & GEO fluxes



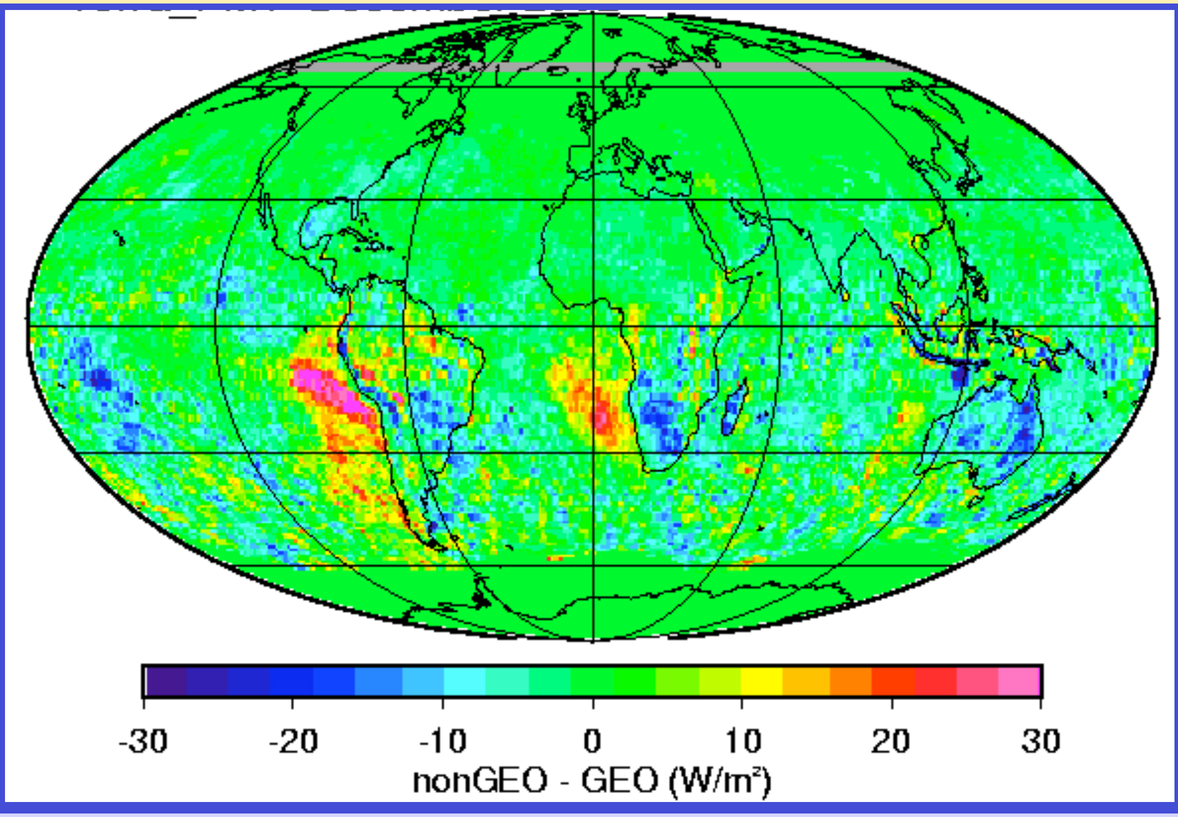
Regional rms=11.7 Wm^{-2} (11.1%)

Regional rms=4.6 Wm^{-2} (4.3%)

- Terra fluxes > Aqua fluxes over marine stratus regions (morning clouds)
- Aqua fluxes > Terra fluxes over land afternoon convection regions
- The merged GEO fluxes have removed the CERES sampling bias of the diurnal cycle

nonGEO - GEO SW monthly mean
Dec 2002

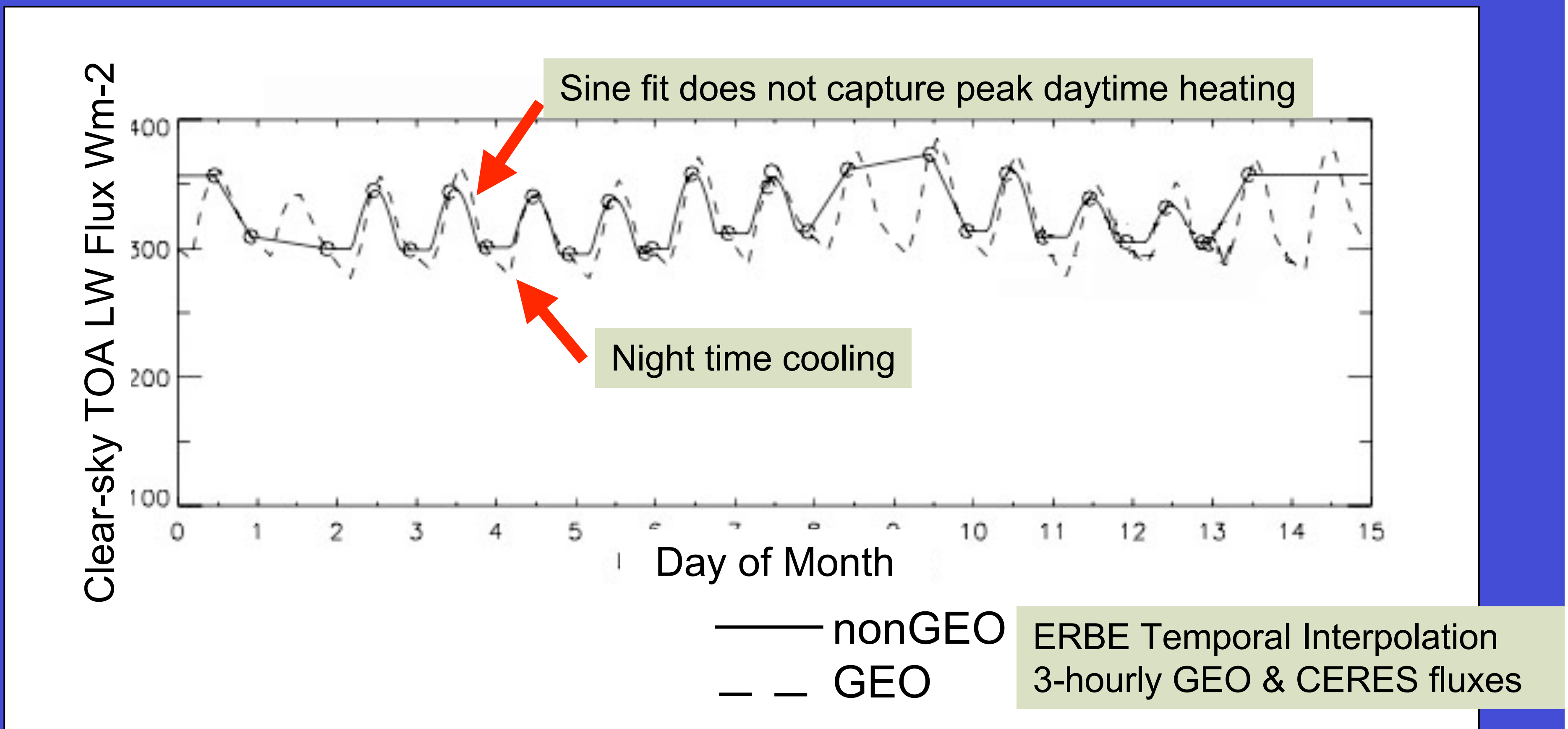
- nonGEO = CERES fluxes and ERBE (constant meteorology) temporal averaging
- GEO = CERES fluxes utilizing GEO fluxes for temporal interpolation



- Regional monthly differences can be > 20 Wm^{-2}
- Global bias is - 1.0 Wm^{-2}

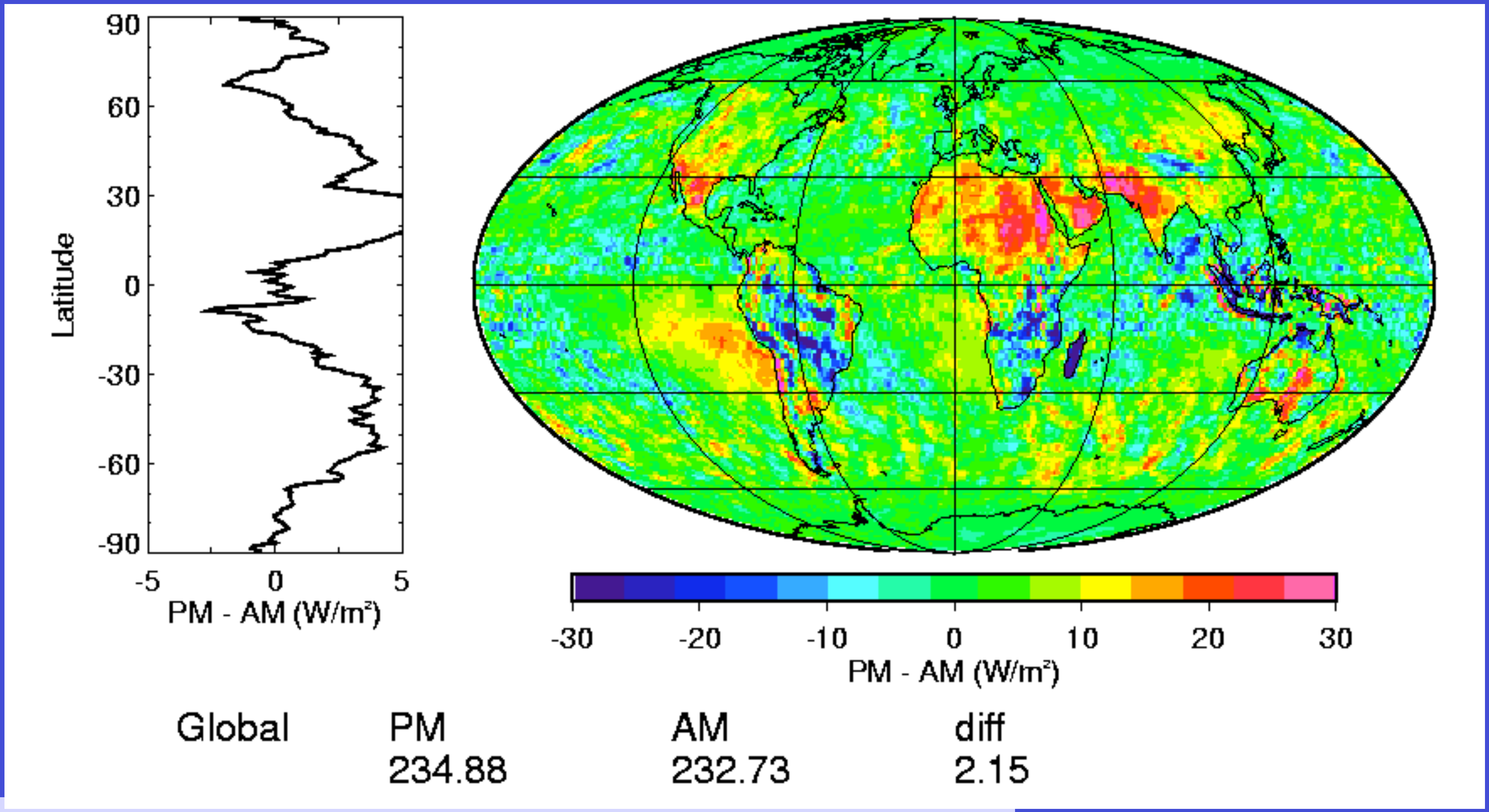
Clear-sky TOA LW Flux

June 2001, Terra FM-1, Arizona Desert



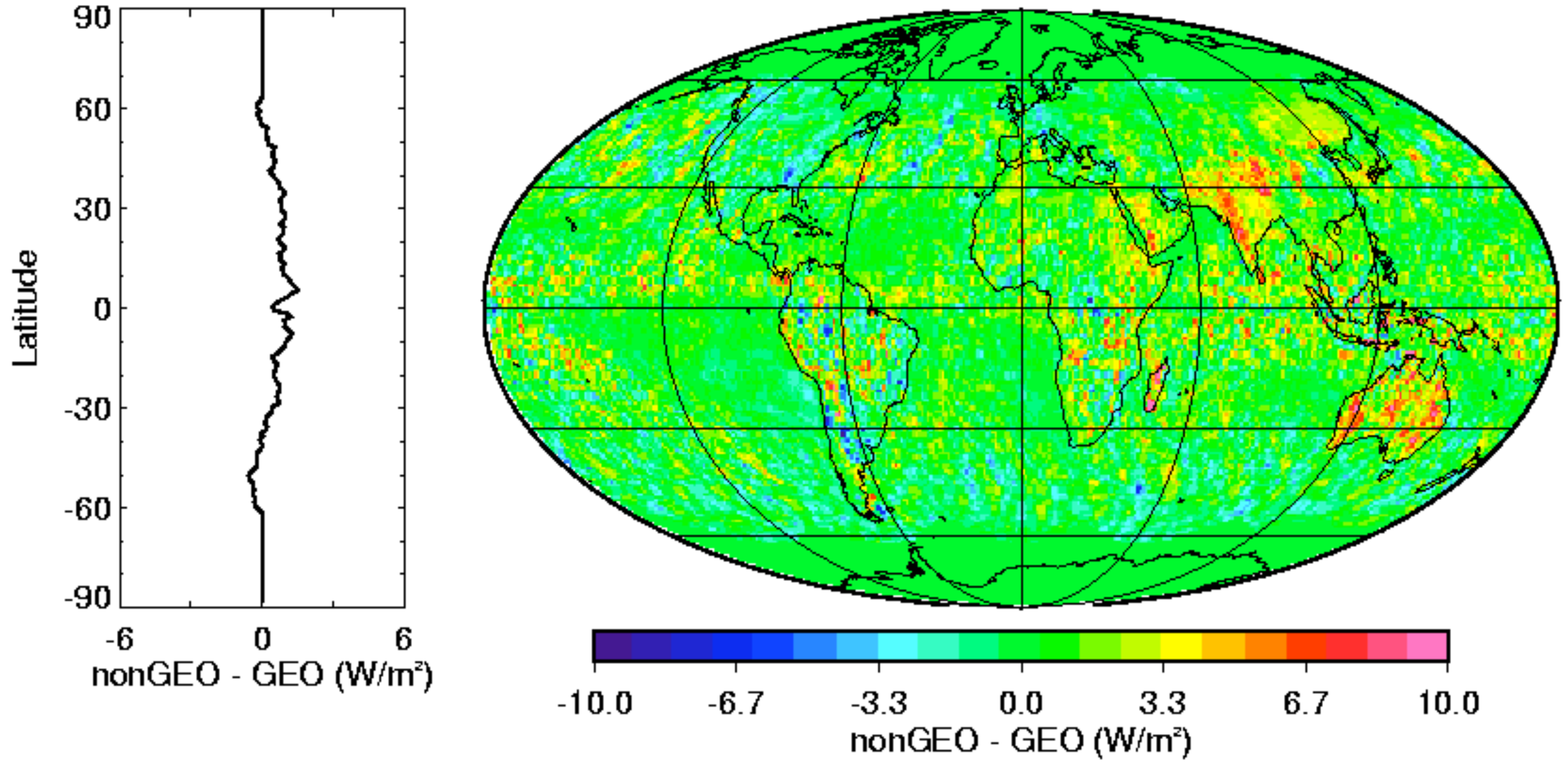
- ERBE temporal interpolation linearly interpolates between measurements over oceans
- Over land a half-sine fit is used to model diurnal heating if night time observations exist

GEO LW 16:30 (PM) - 7:30 (AM) monthly hourly mean Dec 2002



- For land: blue afternoon convection, red thermal lag
- PM-AM differences can be ~ 30 Wm^{-2}

nonGEO - GEO LW monthly mean
Dec 2002



	nonGEO	GEO	nonGEO-GEO	reg RMS
Global	234.26	233.78	0.49	1.97

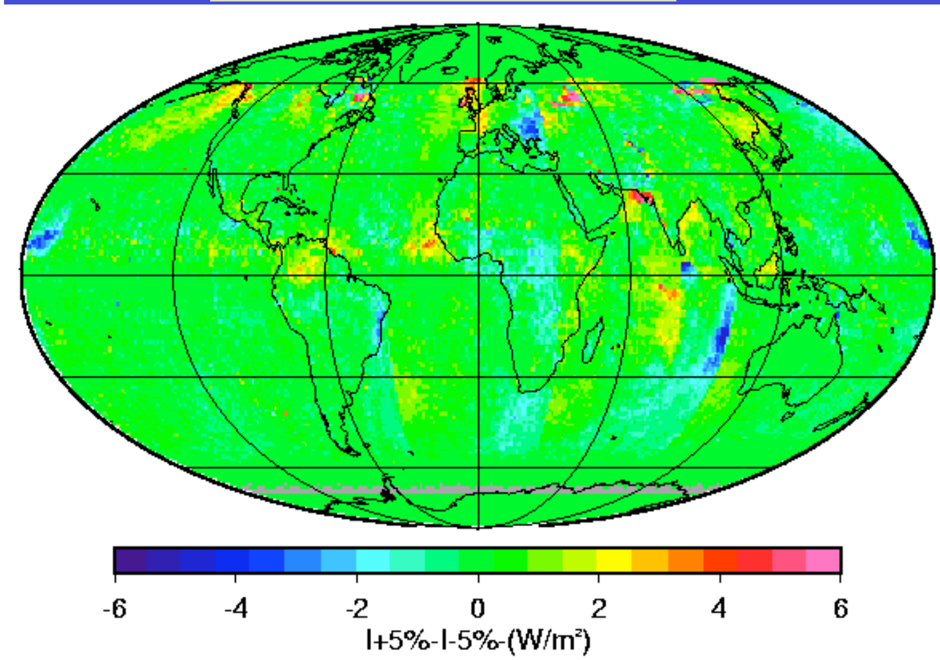
- On a global basis the LW diurnal signal is small

Using Geostationary Data for Temporal Interpolation of TOA Fluxes

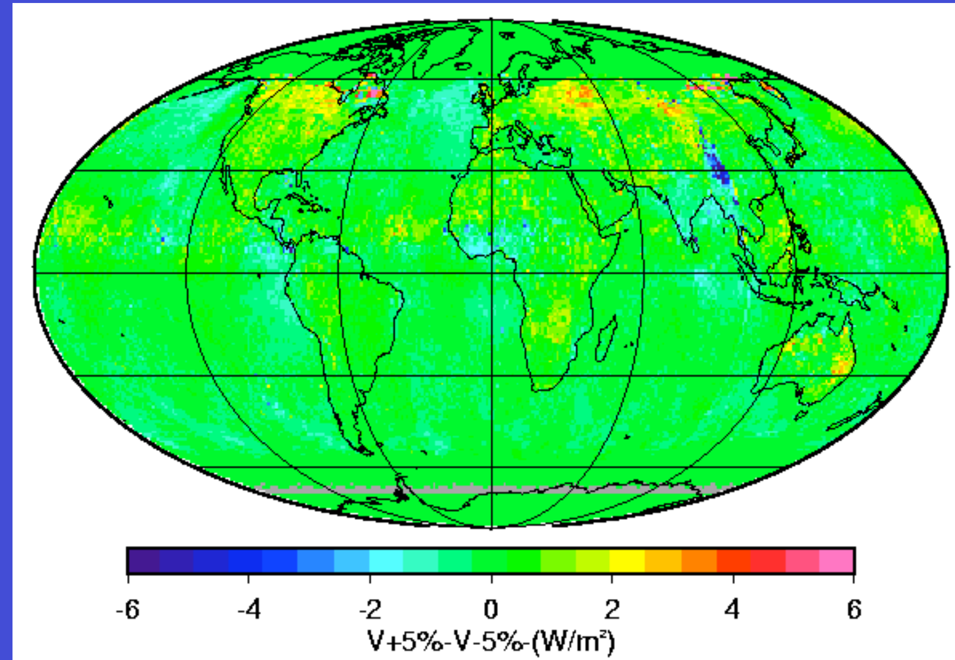
- 3-hourly imager data from geostationary satellites is used to define diurnal variations between CERES observations
  - Terra and Aqua sun-synchronous orbits limit diurnal sampling
- Calibration is critical
  - GEO imagers calibration tied to MODIS, which is well calibrated
- Cloud retrieval is a subset of CERES MODIS algorithm
  - Consistency between CERES and GEO clouds properties
- GEO narrowband to broadband relationships use the same scene identification as the CERES ADMs
- Final fluxes are regionally constrained to CERES observations
  - Maintain the CERES instrument calibration
  - No dependency with region, cloud amount, solar or view angle
  - No GEO artifacts or GEO induced trends over time

Change in Total-Sky TOA SW Flux due to artificial GEO calibration adjustments, July 2002

(IR+5%) - (IR-5%)



(VIS+5%) - (VIS-5%)



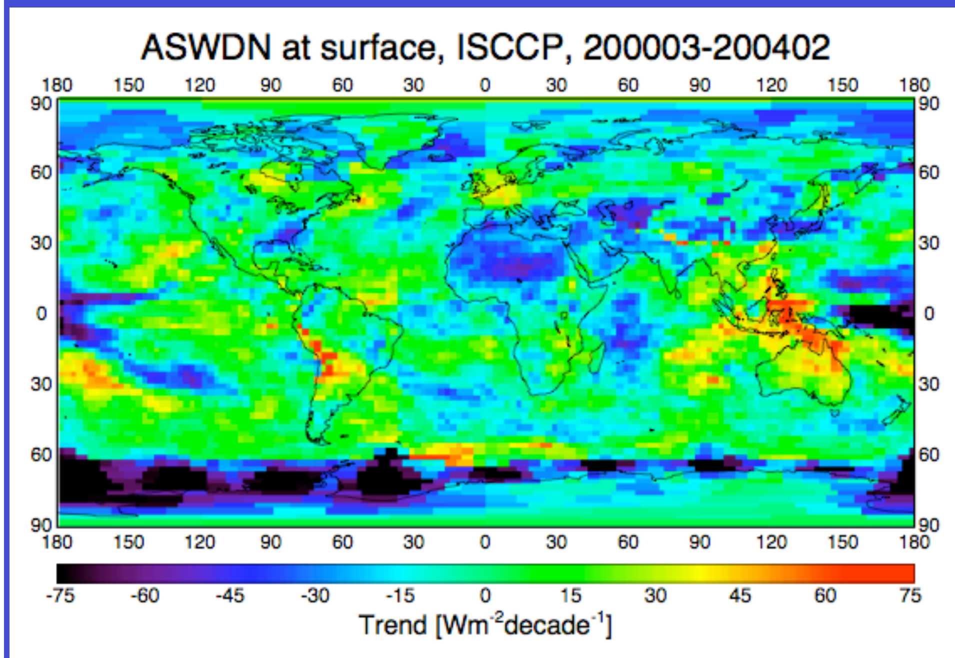
Bias=0.10%,rms=0.9%

Bias=0.01%,rms=0.8%

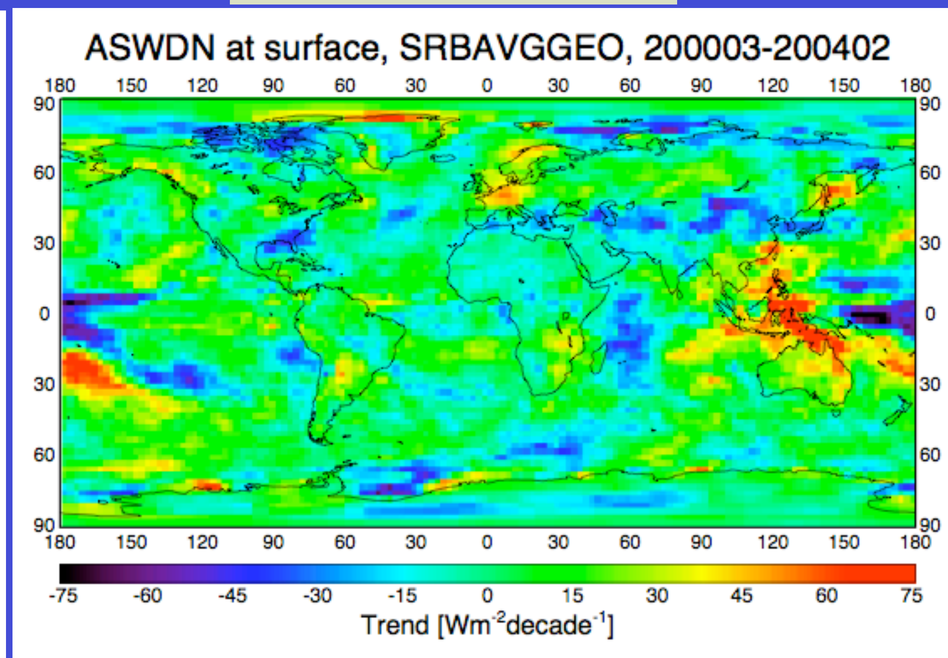
- Plotted differences are for 10% calibration change
- Actual GEO SW calibration uncertainty is 3-5% and LW is 1-2%
- GEO flux constraint to CERES removes sensitivity to GEO calibration

Surface SW down Deseasonalized Trend
March 2000 - February 2004

ISCCP



GEO

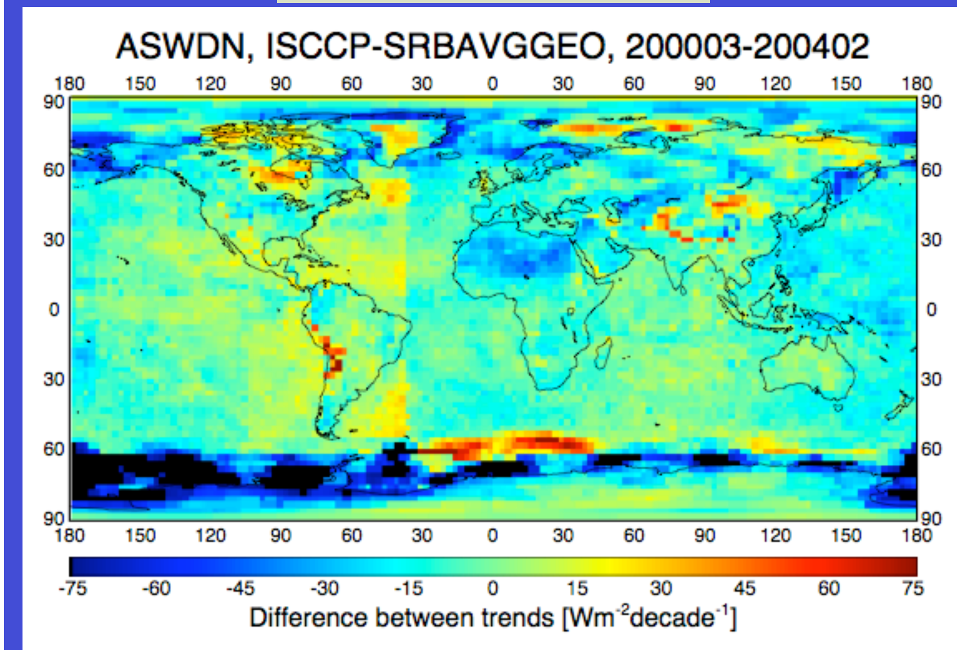


- CERES surface fluxes are parameterized from the CERES and GEO TOA fluxes, cloud properties and GEOS-4 profiles (ISCCP-like generation) using SOFA algorithms

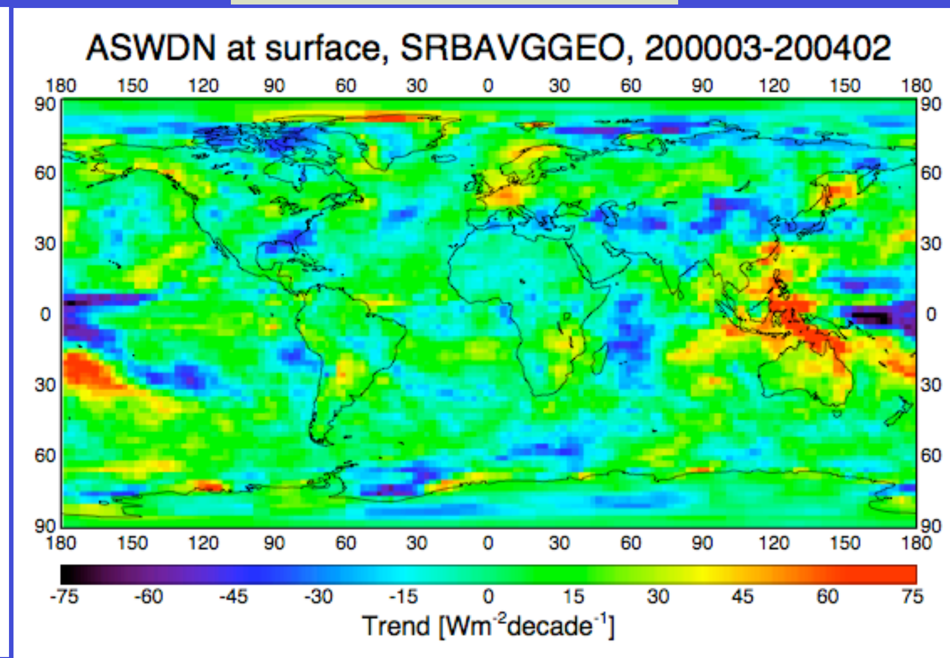
Plots from Laura Hinkelman

Surface SW down Deseasonalized Trend
March 2000 - February 2004

ISCCP - GEO



GEO



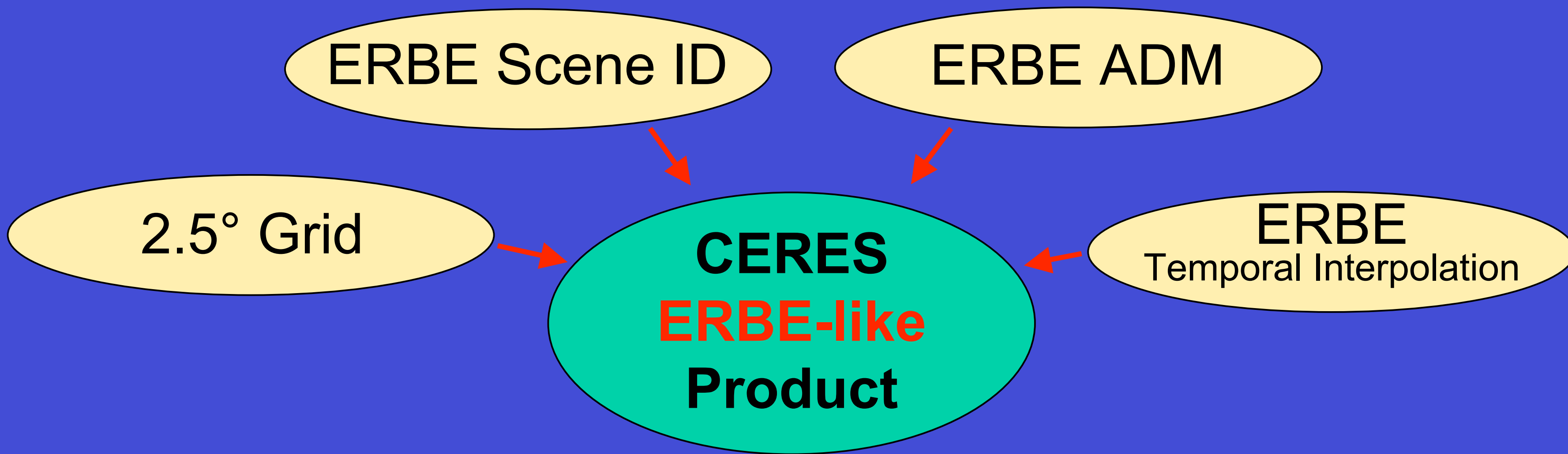
- Unlike ISCCP, GEO fluxes are tied to the CERES TOA fluxes
- No geostationary artifacts are imbedded in the GEO product

CERES Monthly Gridded Products

- CERES products
  - Regional radiative fluxes and cloud properties at TOA, surface and profile levels
- There are 4 main CERES product groups
  - ERBE-like
    - Uses ERBE algorithms to derive fluxes
  - SRBAVG Non-GEO
    - Uses the CERES ADMs and MODIS cloud properties to derive fluxes
  - SRBAVG GEO
    - Adds geostationary fluxes to improve temporal sampling
  - SYN/AVG/ZAVG, Fred Rose presentation tomorrow at 8:30
    - Produces global synoptic maps and radiative transfer fluxes
    - The CERES-Synoptic product fluxes are radiatively consistent with cloud properties

ERBE-like Product

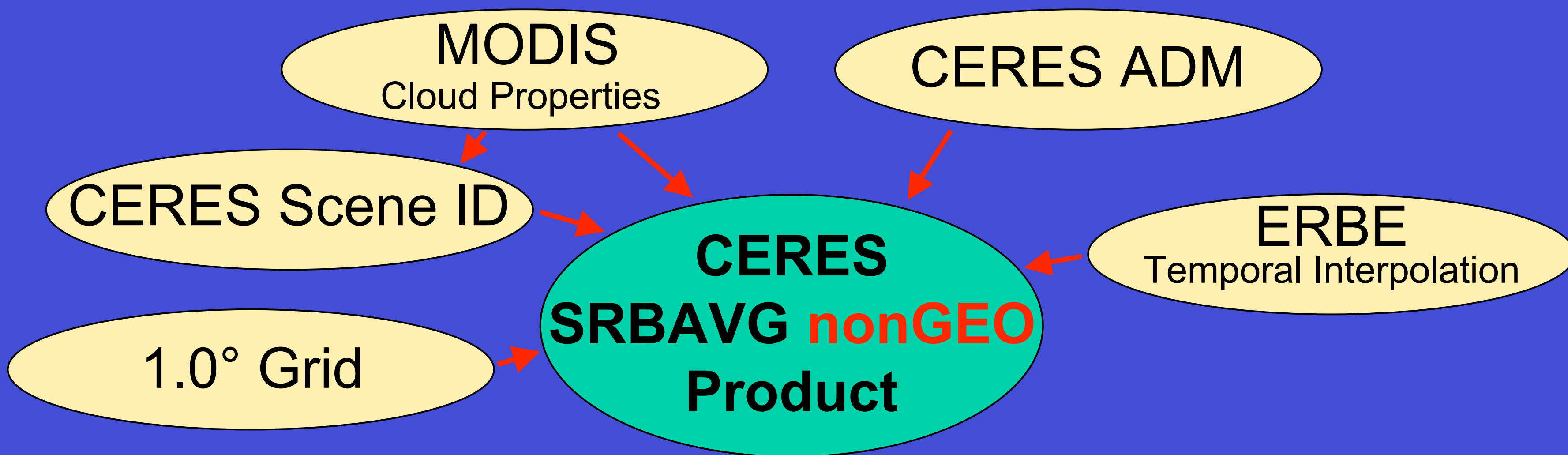
- Product Features:
  - Based on ERBE algorithms and in the same format (ES-4 & ES-9) as the original ERBE scanner dataset (1985-1989)



- Appropriate Usage:
  - To compare with historical ERBE (1985-1989) fluxes to ensure that flux differences are not associated with CERES algorithm improvements

SRBAVG nonGEO Product

- Product Features:
  - TOA fluxes and MODIS cloud properties

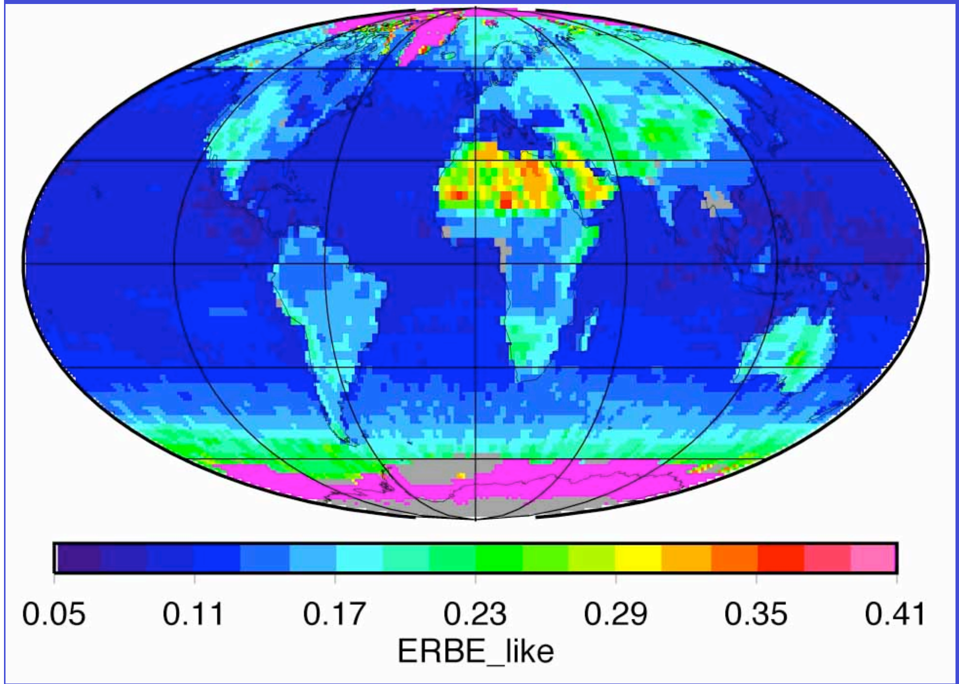


- Fluxes and cloud properties are sampled only during Terra overpasses

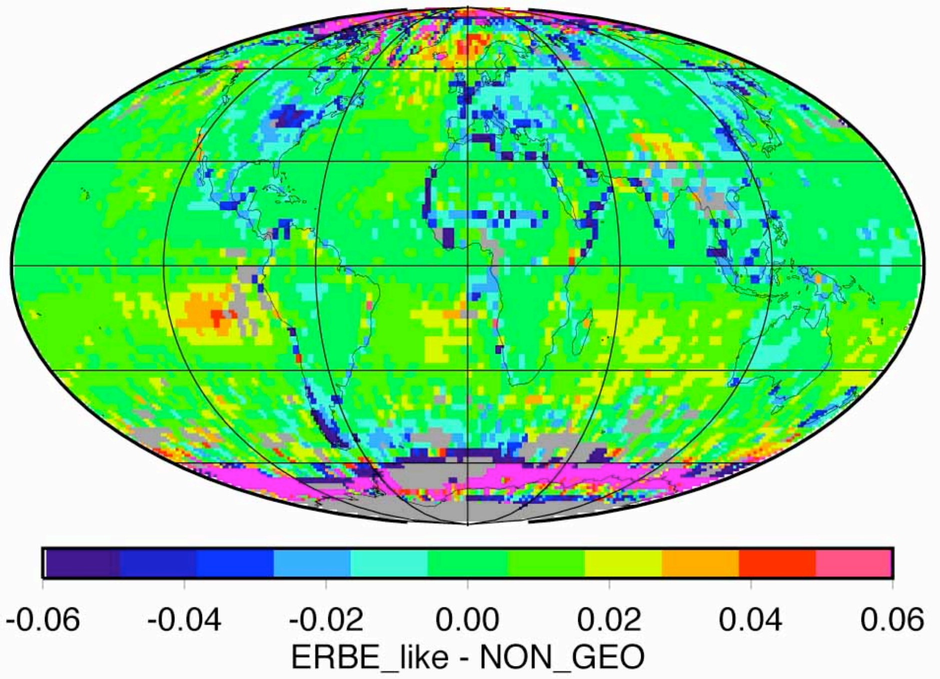
Aug 2002 Clear-sky Albedo

- ERBElike = ERBE scene id, ERBE ADMs, ERBE temporal interpolation
- nonGEO = MODIS scene id, CERES ADMs, ERBE temporal interpolation

ERBE like



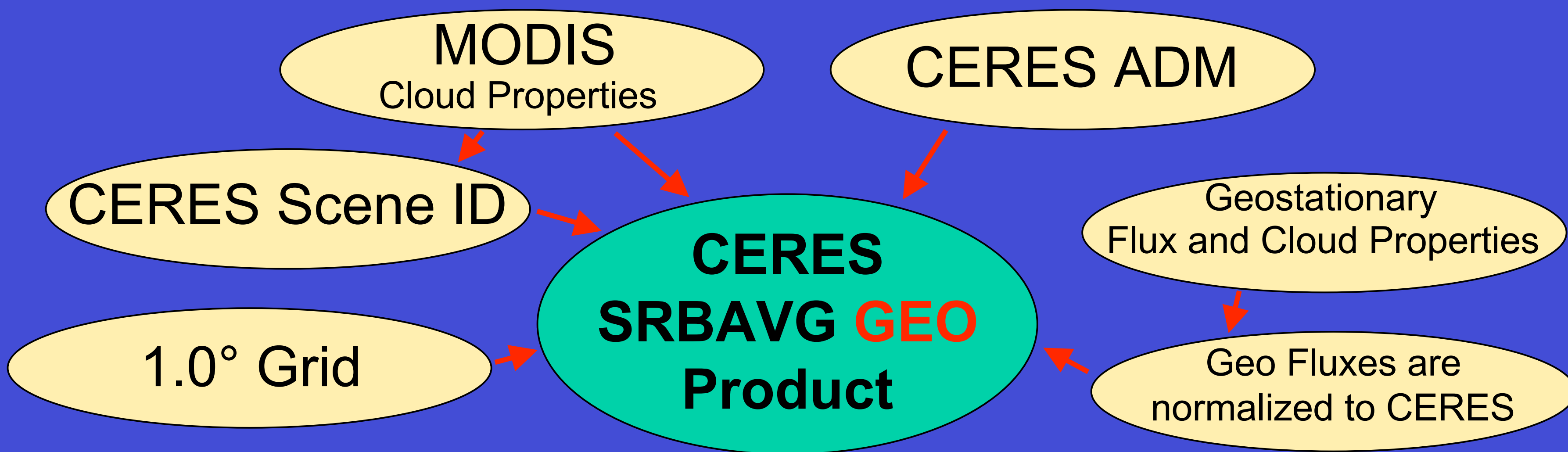
ERBE like - nonGEO



- Note the clear-sky differences over maritime stratus, coastal and polar regions
- The CERES ADMs and scene identification is an improvement over ERBE-like

SRBAVG GEO Product

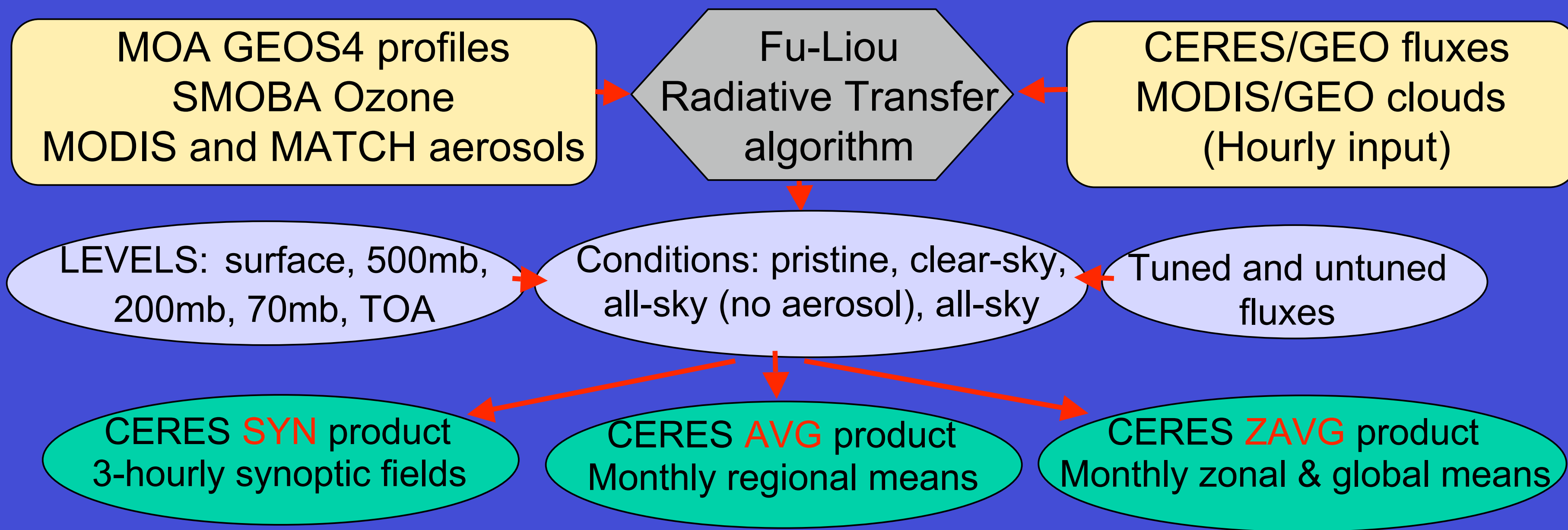
- Product Features:
  - TOA and surface fluxes and MODIS/GEO cloud properties
  - Uses 3-hourly geostationary derived fluxes and cloud properties to interpolate between CERES observations



- The SRBAVG GEO product incorporates the diurnal cycle

SYN/AVG/ZAVG Product

- Product Features:
  - –Surface, TOA, and atmosphere Fu-Liou radiative transfer modeled fluxes consistent with CERES observed TOA fluxes and cloud properties



- SYN fluxes and cloud properties can be compared directly with climate model results at the 3-hourly or monthly level

5 Year Global Mean TOA Fluxes Mar00-Feb05

Wm-2	1986-1988	CERES Mar00 – Feb05		
All-Sky	ERBE	ERBE-like	nonGEO	GEO
OLR	236.3	239.0	237.7	237.1
SW	101.1	98.3	96.6	97.7
NET	4.9	4.0	7.0	6.5

ADM improvement

Diurnal improvement

• Net imbalance within envelope of systematic errors (next slide)

Global Net Flux Balance Error Budget

(out of 1365/ 4 = 341.25 Wm^{-2} = SW + LW)

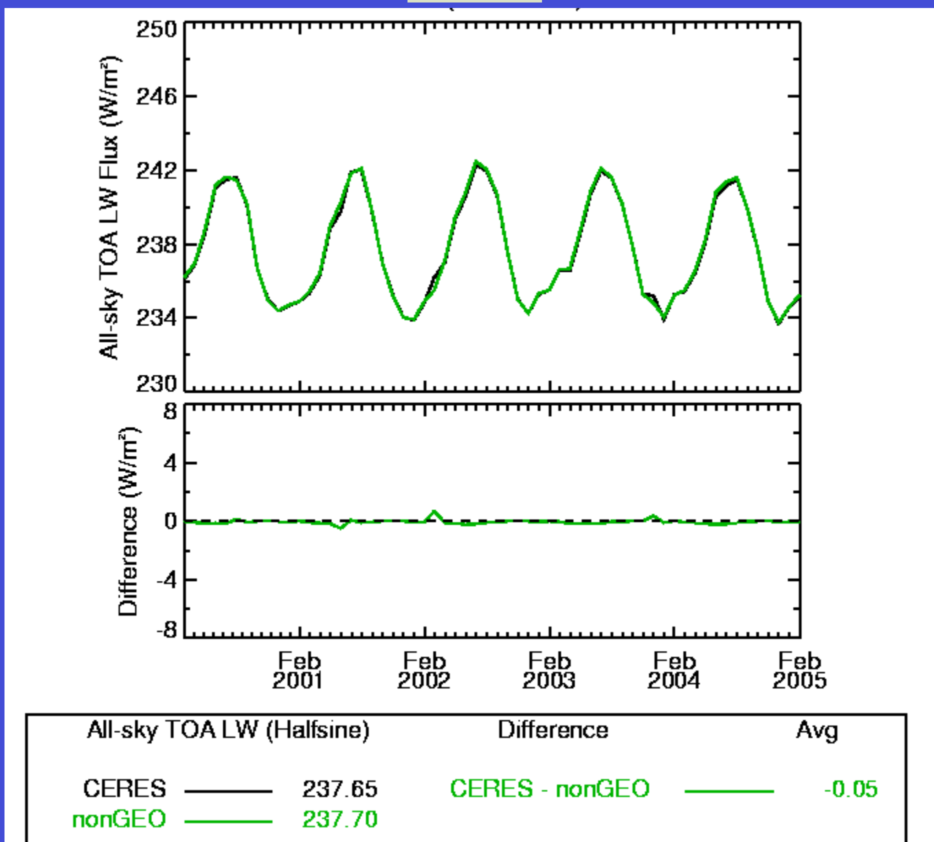
- Error Source (yellow = heating) SW LW Net
- Solar Constant (1361 vs 1365) + 1.0 0.0 + 1.0
- Non-Spherical Earth (S_o/4.0045 not 4) + 0.4 0.0 + 0.4
- Absolute Calibration (2 sigma) 2.0 2.0 4.0
- Spectral Correction 0.5 0.3 0.6
- Spatial Sampling < 0.1 < 0.1 < 0.1
- Angle Sampling (ADMs) + 0.2 - 0.1 + 0.1
- Time Sampling (diurnal) < 0.2 < 0.2 < 0.2
- Reference Altitude (20km) 0.1 0.2 0.3
- Near Terminator SW Flux +0.3 to 0.5 0.0 + 0.3 to 0.5
- Ocean Heat Storage + 0.4 to + 0.8
- Expected Global Net Range: - 1.5 to + 6.6
- CERES SRBAVG Ed2D Rev 1 Global Net + 6.4
- *Will provide community with advice for optimal global "closure"*

Net Flux Optimal Global Closure

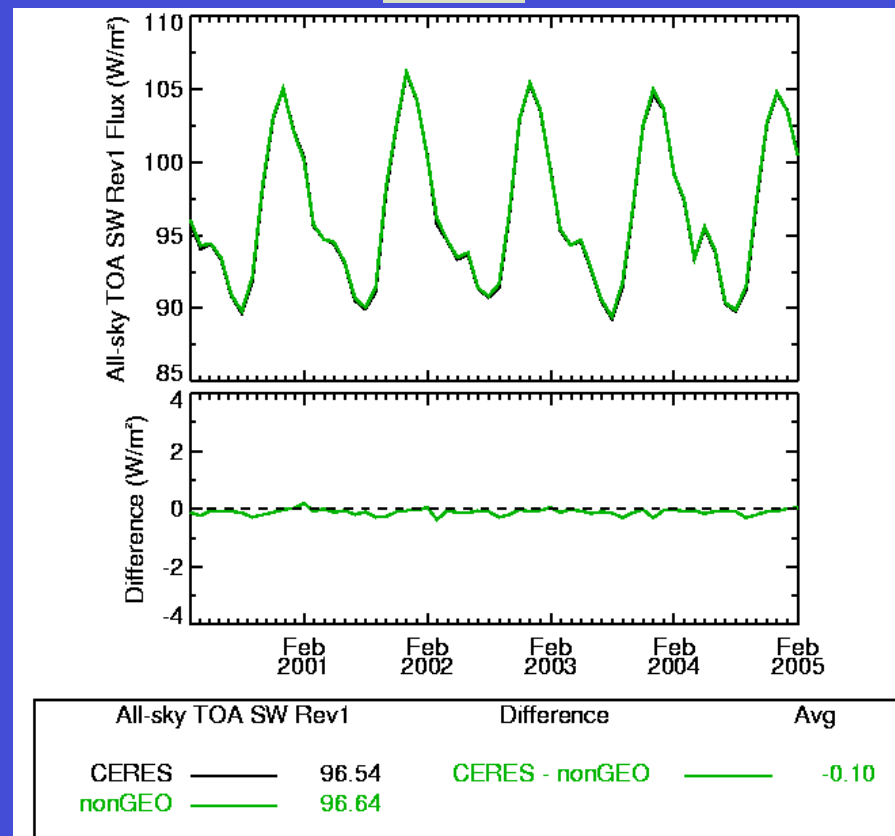
- Objective is to close the net flux imbalance by adjusting SW & LW TOA fluxes according to known uncertainties (previous slide).
- The adjustment will also incorporate preliminary Edition3 instrument calibration improvements.
- Apply TISA temporal interpolation to Norm's daily SSF database
  - Able to sidestep CERES production, process 5 years in 1 day
  - Compare with SRBAVG nonGEO fluxes
  - Multiple day or night satellite overpasses are summed in the daily database

Database - nonGEO All-sky Timlines

LW



SW



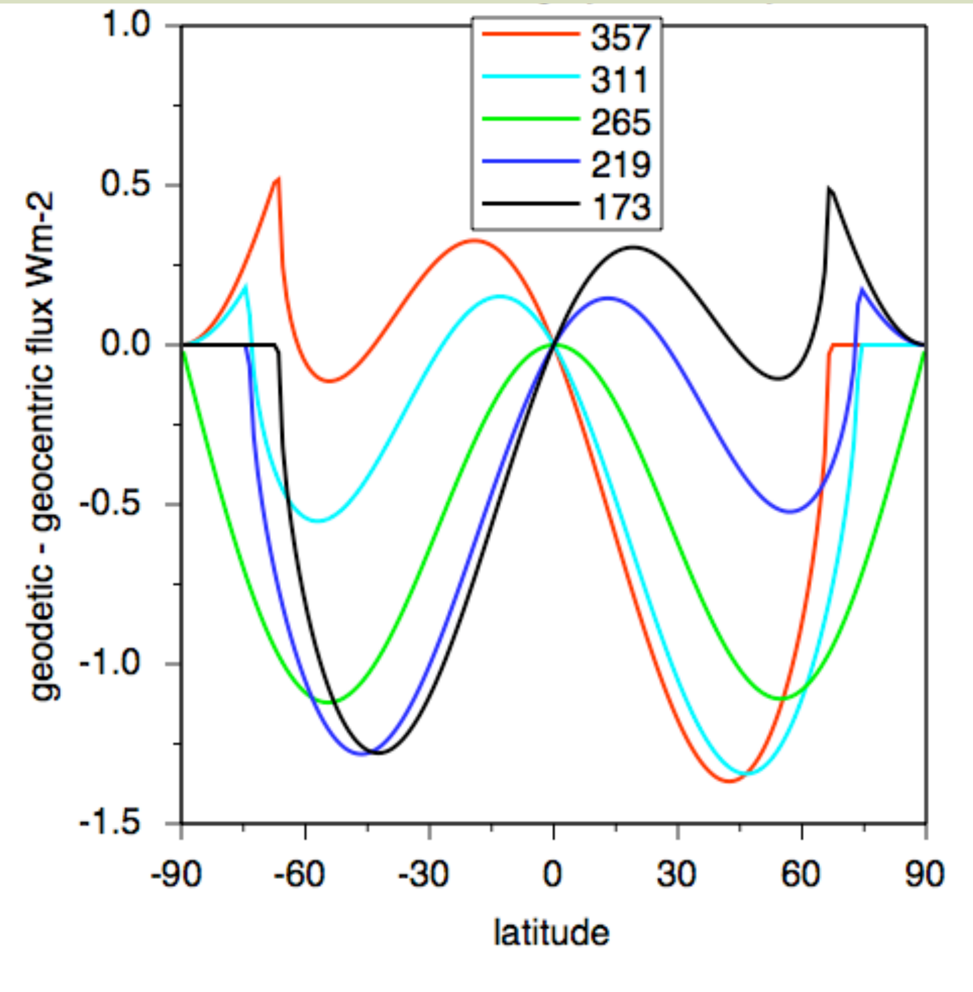
- Annual differences < 0.1 Wm-2

Comparison of Geodetic and Geocentric (Elliptical - Spherical) Earth

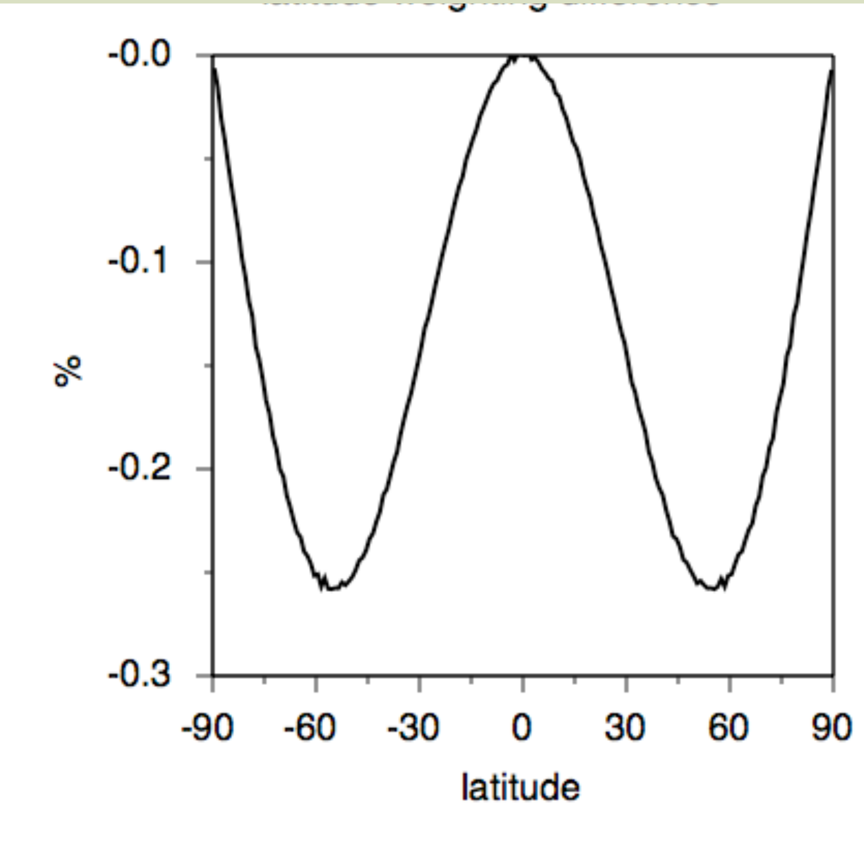
- Currently the CERES TISA Ed2 products assumes a spherical earth to derive the global from the zonal mean
  - The SFC grids the footprints in geodetic latitude
- Both the solar incoming flux and area weighting are effected
  - The solar zenith angle is always slightly greater geodetically, there for the solar incoming should be smaller
    - Depends on the declination angle or julian day
  - The equator is weighted more geodetically
    - Will impact both the OLR and SW reflected
- To derive the annual mean, need to weigh the monthly means by the number of days in the month
  - A simple 12 month average results in a 0.045 Wm-2 increase in the solar incoming flux

Comparison of Geodetic and Geocentric (Elliptical - Spherical) Earth

Solar Incoming Difference

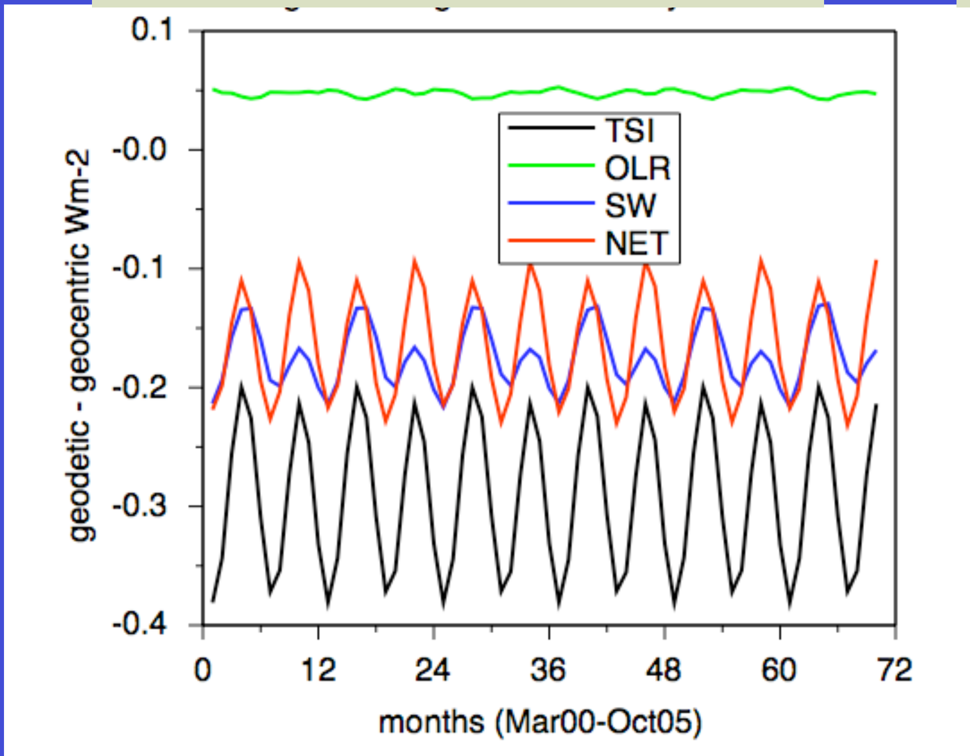


Zonal Weighting Difference

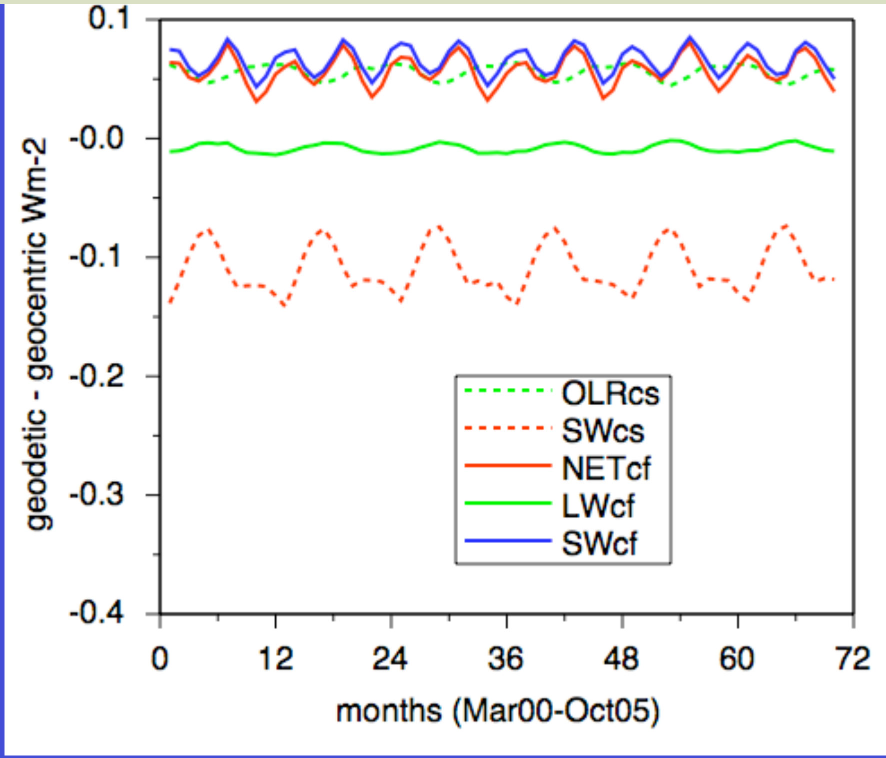


Comparison of Geodetic and Geocentric (Elliptical - Spherical) Earth

All Sky Fluxes



Clear-sky & Cloud Forcing Fluxes



- Annual Means

60 month ave	SW	LW	NET	TSI
All-Sky	-0.18	+0.05	-0.16	-0.30
Clear-Sky	-0.11	+0.06	-0.24	
Cloud Forcing	+0.07	+0.01	+0.07	

SRBAVG-Daily on Ed2E

- Separate the GEO and nonGEO flux and cloud parameters
  - SRBAVG-daily1 is the GEO (GEO & CERES) TOA, surface fluxes and clouds
  - SRBAVG-daily2 is the nonGEO (CERES-only) TOA fluxes and MODIS clouds
- SRBAVG-daily2: also includes the MODIS product aerosols
  - 0.65µm and 1.6µm (Ignatov aerosols) in SRBAVG1 product
  - Monthly zonal incoming solar flux
  - Daily Snow/Ice coverage maps (snow+ice+IGBP)
- Make sure the average of the daily fluxes is equivalent to the SRBAVG monthly mean
  - Except nonGEO clear-sky LW, SRBAVG uses monthly half sine fit, whereas Daily will use daily half sine fits
- Corrects the RAPS mode GGEO/CERES SW normalization error

ISCCP-D2-like

- GOAL: produce 9 GMT 3-hourly monthly mean cloud properties consistent with ISCCP D2 product format
  - Average cloud properties as a function of ISCCP cloud types based on cloud height and optical depth
  - User community already familiar with data format, to describe the dynamic state

- MODIS-only derived from SSF, one daytime measurement (Terra 10:30AM, Aqua 1:30PM)
  - Multi-channel retrieval, 42 cloud types
- GEO-only from 5 geostationary satellites, from 3-hourly images (60°N-60°S)
  - Daytime VIS and IR, and night time IR only retrievals, 9 cloud types
  - GGEO based on 4 cloud layers. Use gamma distribution to derive optical depth bins.

CERES Instaneous Gridded Data Products

CERES PRODUCT	TRMM	Terra	Aqua
ERBE-like ERBE gridded ES-8 fluxes	**Ed2** **Jan98-Aug98 & Mar00**	**Ed1CV**(Mar00-Aug07) **Ed2** (Mar00-Dec06)	**Ed1CV** (Jul02-Aug07) **Ed2** (Jul02-Dec06)
SSF/SFC CERES local time gridded fluxes and cloud products from SSF	**Ed2B** **Jan98-Aug98 & Mar00**	**Ed2C** (Mar00-Jul06) **Ed2F** (May06-Dec06) *MODIS Collection5* **Dec 07**	**Ed2A/B**(Jul02-Apr06) **Ed2C** (May06-Dec06) *MODIS Collection5* **Dec 07**
ISCCP-like-MODIS Pc-Tau GMT 3-hourly cloud statistics		**Ed2B/F**(Mar00-Dec06) **July 2008** *After same as SSF*	**Ed2B/C**(Jul02-Dec06) **August 2008** *After same as SSF*
CRS/FSW CERES GMT synoptic gridded fluxes from SSF and CRS	**Ed2C** **Jan98-Aug98 & Mar00**	**Ed2C** (Mar00-Dec05)	**Ed2A/B**(Jul02-Apr06)
SYN SARB 3-hourly syntopic gridded parameters		**Beta3** (Mar00-Sep04) **Beta4** (Mar00-Oct05) *Seasonal months* **May 2008** **Ed2C** (Mar00-Dec05) **November 2008**	**Beta1** (Jul02-Oct05) *Seasonal months* **Jun 2008** **Ed2B** (Jul02-Dec05) **February 2009**

- **Completed, Projected**
- Users must apply REV1 to all Ed2 SW fluxes, except SYN/AVG/ZAVG, procedure in DQS

CERES Monthly Gridded Average Data Products

CERES PRODUCT	TRMM	Terra	Aqua
ERBE-like Monthly mean ERBE-like product, ES-4, ES-9	**Ed2** **Jan98-Aug98 & Mar00**	**Ed1CV**(Mar00-Aug07) **Ed2** (Mar00-Dec06)	**Ed1CV** (Jul02-Aug07) **Ed2** (Jul02-Dec06)
SRBAVG Monthly mean nonGEO and GEO products	**Ed2B** **Jan98-Aug98 & Mar00**	**Ed2D** (Mar00-Oct05)) **Ed2E** (Mar00-Dec05) *includes daily* July 2008 **Ed2E/F** (Jan06-Dec06) October 2008	**Ed2A** (Jul02-Oct05) January 2008 **Ed2B** (Mar00-Dec05) *includes daily* July 2008 **Ed2B/C**(Jan06-Dec06) October 2008
ISCCP-like-GEO Pc-Tau GMT 3-hourly cloud statistics	**5 Geostationary Satellites Ed2A** (Mar00-Dec06) November 2008		
AVG/ZAVG Monthly mean synoptic SARB product		**Beta3** (Mar00-Sep04) **Beta4** (Mar00-Oct05) *Seasonal months* May 2008 **Ed2C** (Mar00-Dec05) November 2008	**Beta1** (Jul02-Oct05) *Seasonal months* Jun 2008 **Ed2B** (Jul02-Dec05) February 2009

- **Completed, Projected**
- First look SSF and daily gridded CERES fluxes are available as **FLASHFLUX**
  - Available within 6 days of real-time,archive begins with March 2006
  - Version SSF uses the same CERES ED2 routines using latest calibration and GEOS dataset
  - Beta TISA gridded product uses the nonGEO ED2 algorithm but combines Terra and Aqua
  - http://eosweb.larc.nasa.gov/PRODOCS/flashflux/table_flashflux.html

Conclusions

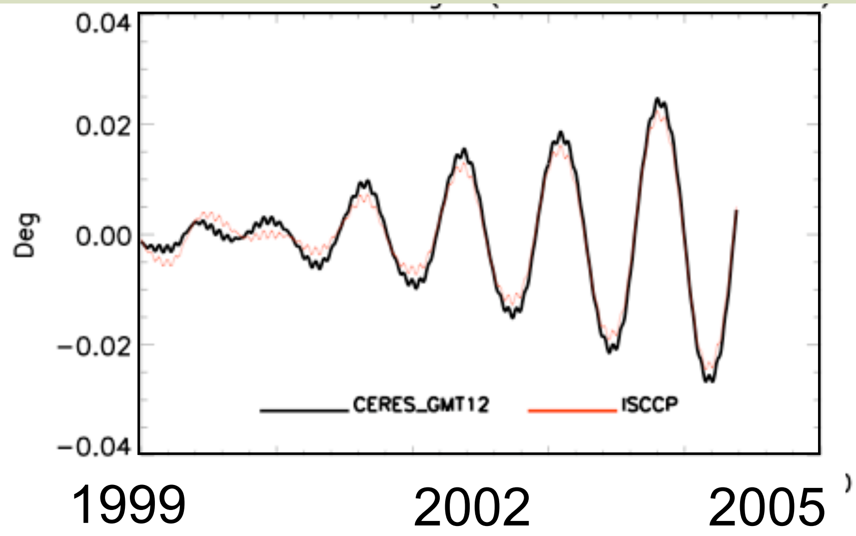
- Adding in geostationary fluxes with CERES fluxes completes the diurnal signal in the radiation budget
  - The CERES GEO product represents a major improvement over currently available global Earth energy budget datasets
  - Regional monthly mean fluxes can be greater than 20 Wm-2 from ERBE-like
- The CERES-GEO product fluxes are of climate quality
  - GEO fluxes are constrained to CERES
  - No GEO artifacts or trends observed
- The CERES-Synoptic product fluxes are radiatively consistent with cloud properties

Comparison of Ephemeris datasets

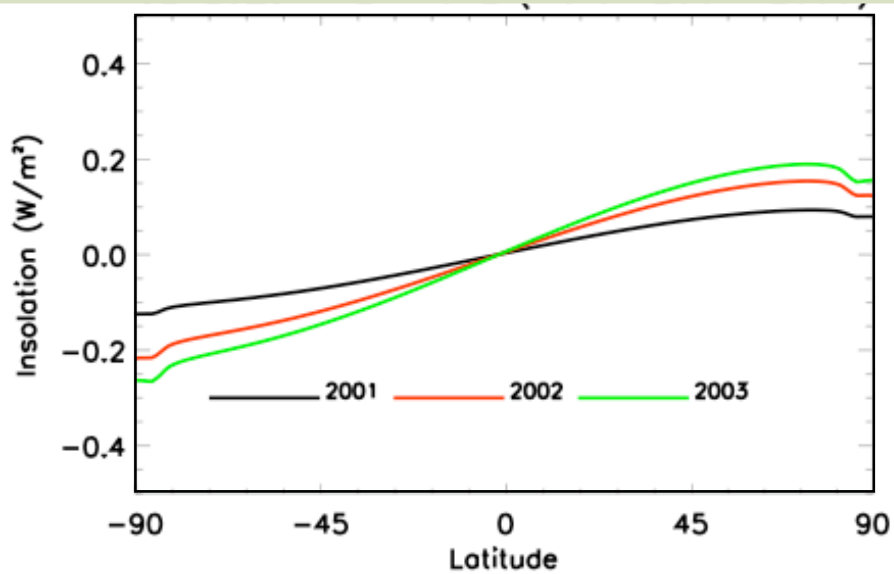
- Climate datasets do not have a standardized ephemeris dataset or solar constant
  - Should always normalize fluxes to the same incoming solar before comparing trends or differences in the SW fluxes
  - Especially true in polar regions
- Compare the solar incoming difference from JPL De405 (reference) and the CERES EOSlib almanac
- CERES TISA datasets (SFC, SRBAVG Ed2D) have their daily ephemeris based on 00 GMT instead of 12
  - What is the impact?
  - SYN/AVG/ZAVG updates the ephemeris hourly
  - Will correct in SRBAVG Ed2E

Comparison of CERES - JPL De405

Solar Declination difference



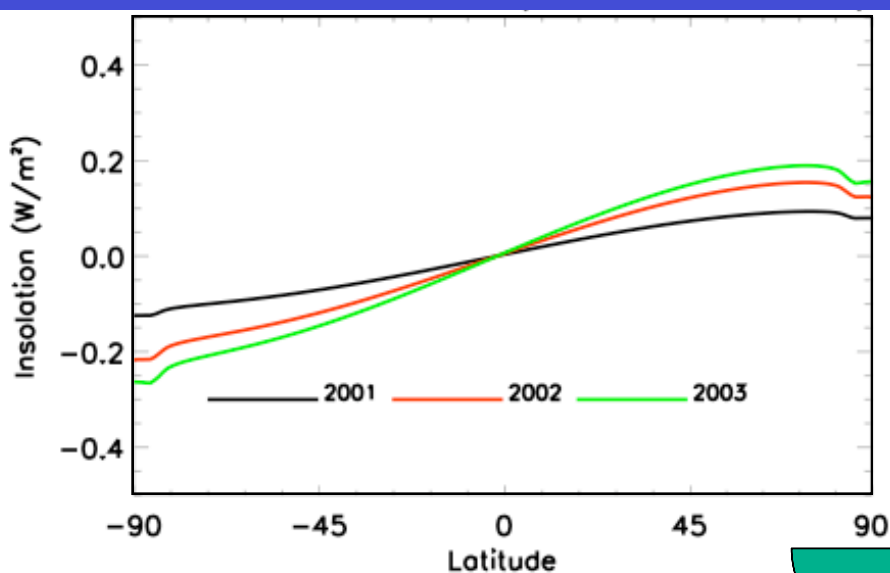
March Solar insolation zonal difference



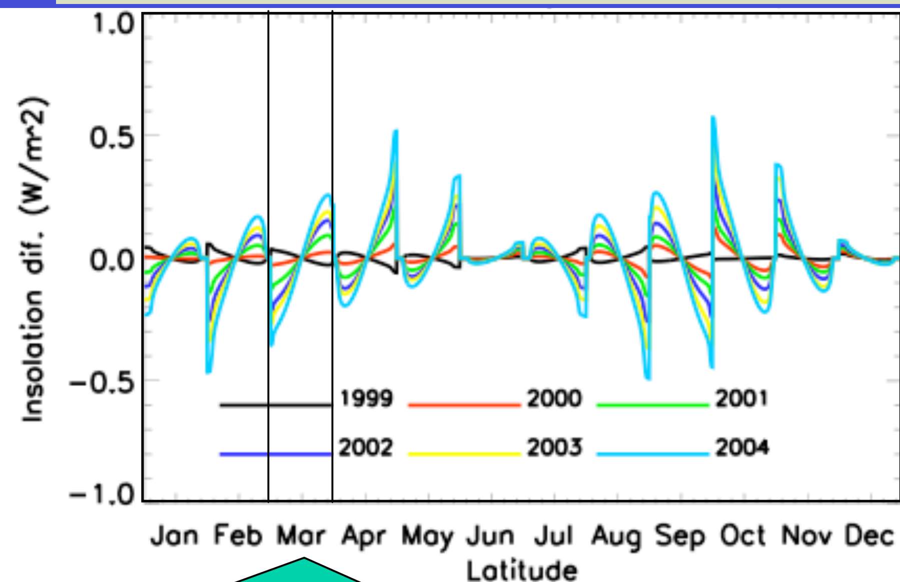
- CERES uses the **CCSDS 301.0-B-2 (1994)** almanac
- CERES uses **JPL De200** earth sun distance

Comparison of CERES - JPL De405 Solar Insolation difference

March Zonal difference



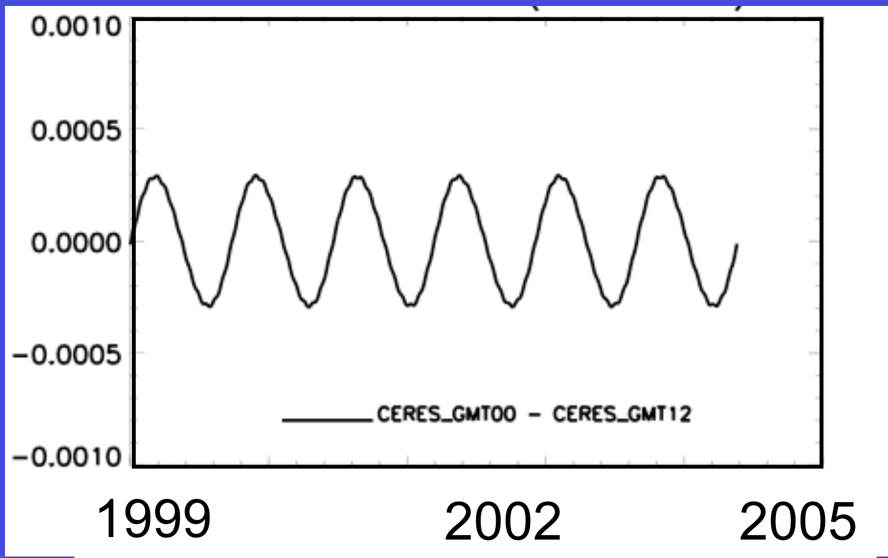
12 month zonal difference



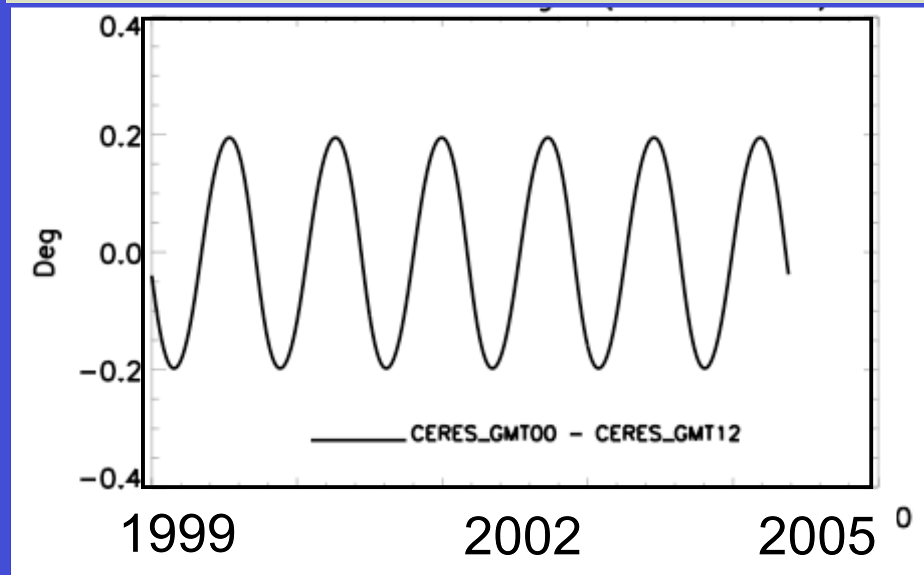
- Seasonal difference variation of ±.001

Comparison of Ephemeris based on 00 - 12 GMT

Earth-Sun distance (AU)



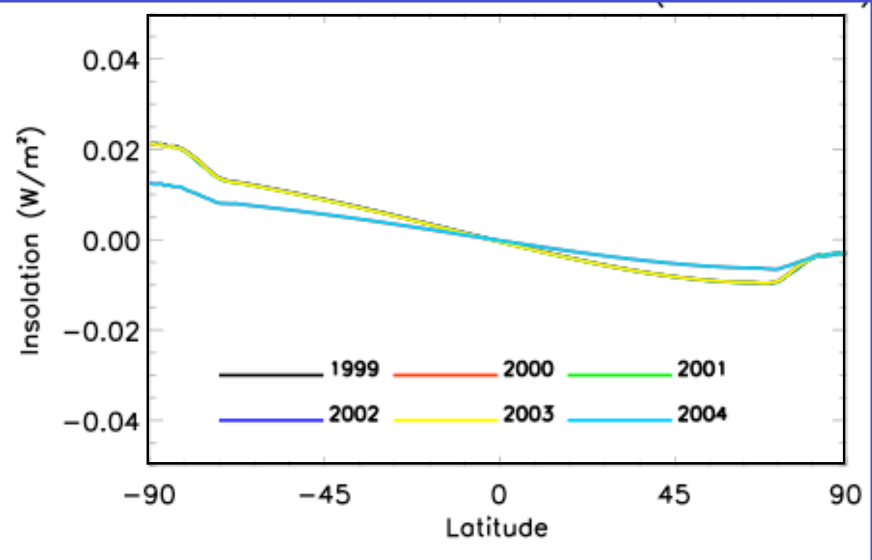
GMT00-GMT12 Declination Angle



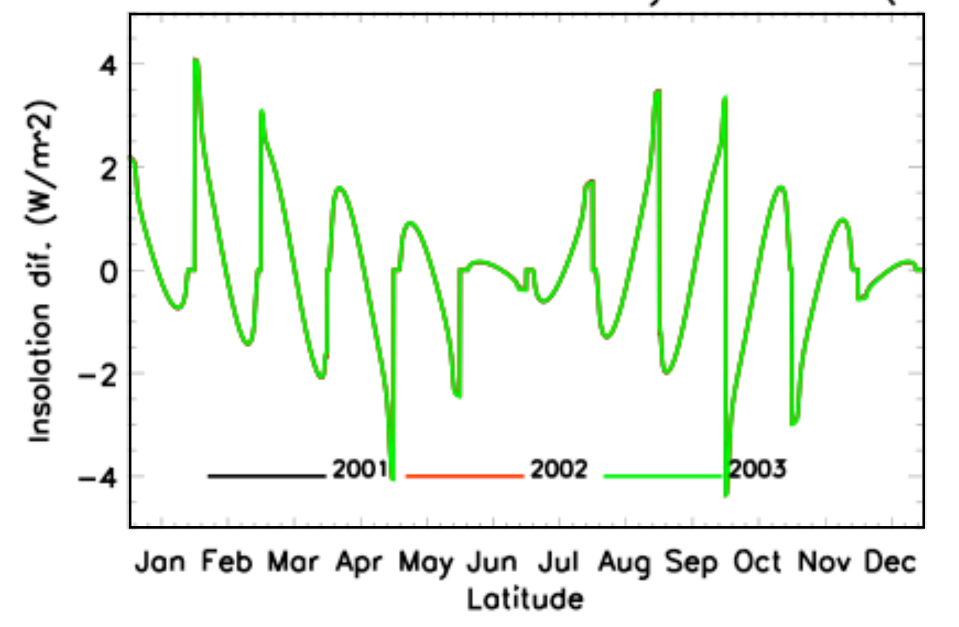
- CERES TISA code in error
- Daily Ephemeris based on GMT00 rather than GMT12

Comparison of Solar Insolation of 00 - 12 GMT Ephemeris

Annual Zonal Difference



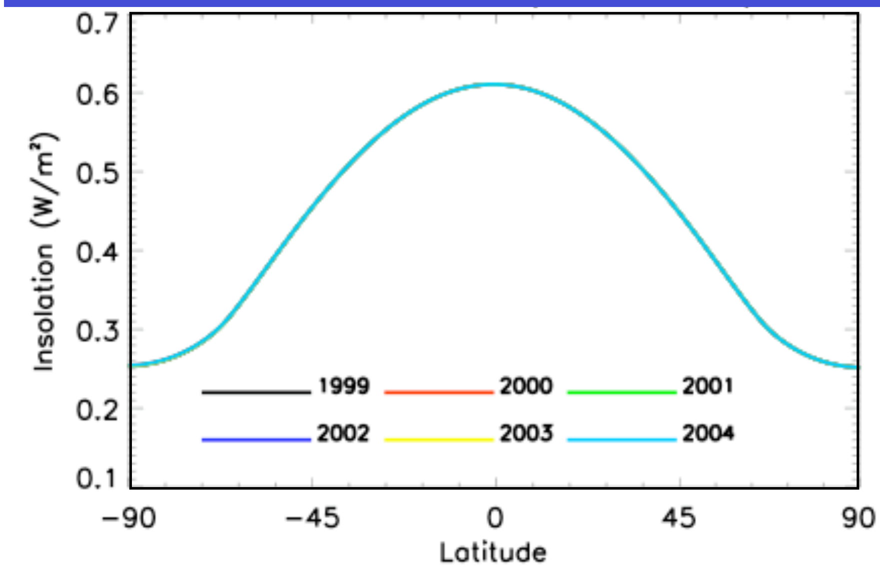
12 month Zonal Difference



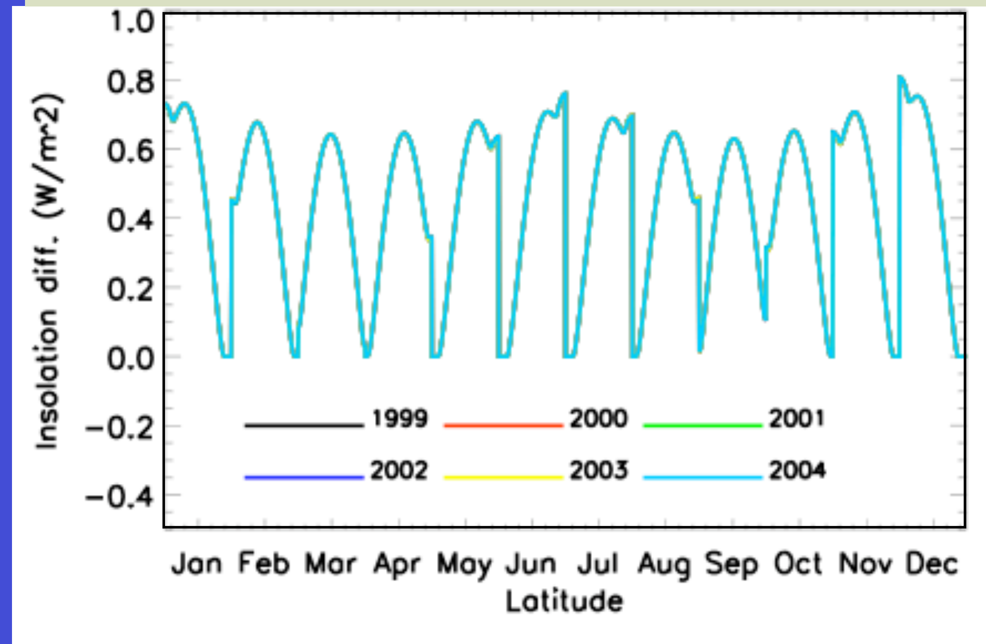
- Seasonal difference variation between ±0.1 Wm-2

Comparison of Solar Constant difference of 1367 and 1365

Annual Zonal Difference



12 month Zonal Difference

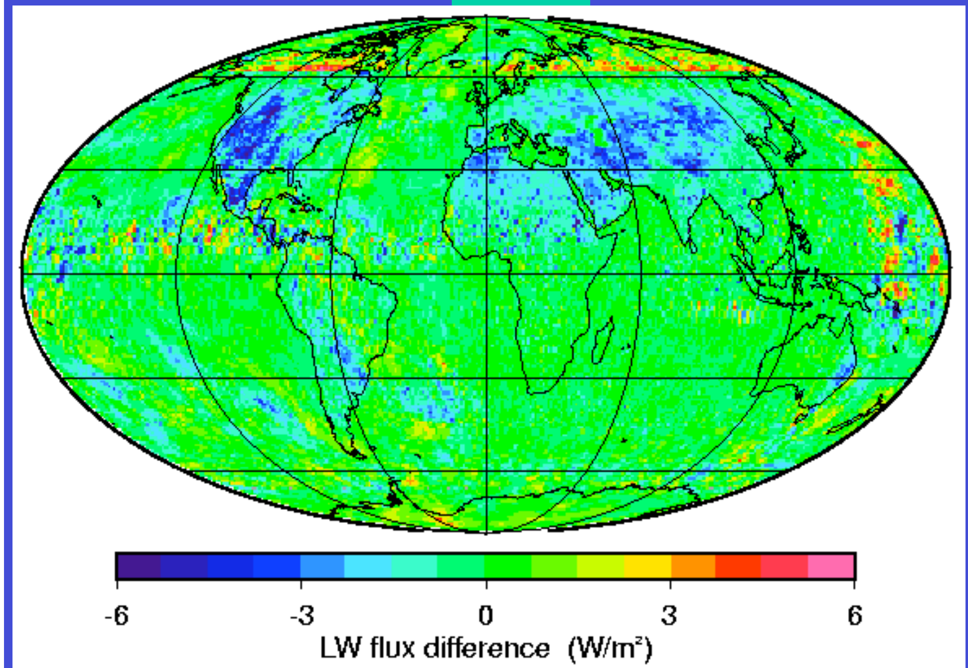


- Seasonal difference variation between 0.52 and 0.48 Wm-2

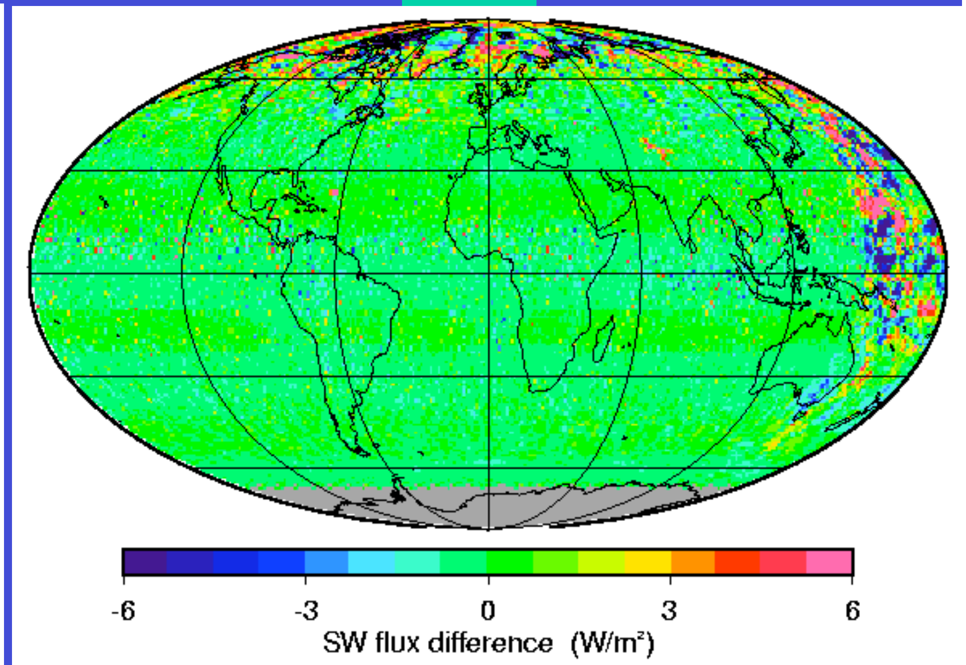
Backup slides

Daily Dataset - nonGEO all-sky flux July 2002

LW



SW



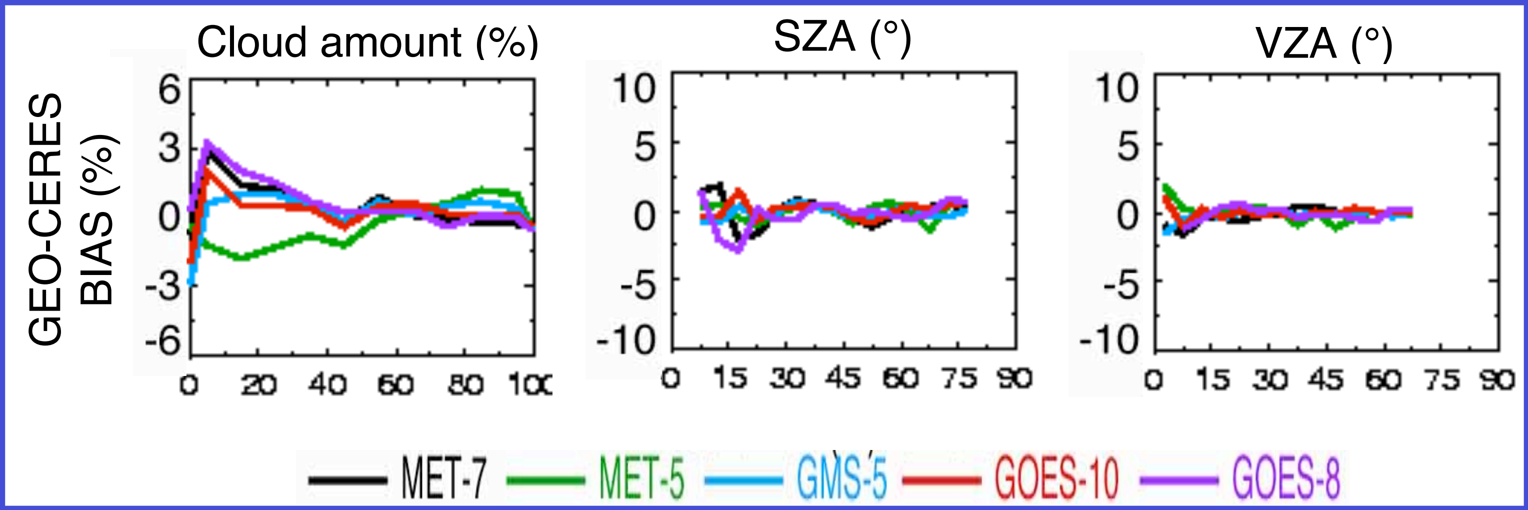
ISCCP 15 daytime cloud types

Cloud top (mb)			
High 50-440	Cirrus ice=13	Cirrus-stratus ice=14	Deep Convective ice=15
Mid 440-680	Alto-cumulus liq=7, ice=10	Alto-stratus liq=8, ice=11	Nimbo-stratus liq=9, ice=12
Low 1000-680	Cumulus liq=1, ice=4	Strato-cumulus liq=2, ice=5	Stratus liq=3, ice=6
Cloud optical depth	0.0-3.6	3.6-23	23-380
	Thin	Mid	Thick

SRBAVG-ISCCPd2like parameters

Cloud Parameter	MODIS-only	GEO-only
Cloud Fraction	X	X
Effective Pressure	X	X
Effective Temperature	X	X
Optical Depth	X	X
Liquid/Ice Water Path	X	X
Particle size (radius, diameter)	X	
Infrared Emissivity	X	
# of days/GMT box	X	X

SW GEO-CERES Ocean Biases for Jan 2001



• GEO Biases <3% as a function of cloud amount, SZA and VZA

Summary of SRBAVG Ed 2D consistency checks

	SW		LW	
(%)	Bias	RMS	Bias	RMS
Terra-Aqua (instantaneous) (day/night)	0.3 to 0.7	15.0	0.2 to 0.7 -0.5 to –0.3	4.6 4.5
Terra-Aqua (monthly)	1.0	4.2	-0.3	0.9
Surface (monthly)	3.2	11.3	0.0	3.1
SARB (instantaneous)	3.5	14.4	-0.6	5.1
GEO Calibration(monthly)	<0.1	<1.0	<0.1	<1.0
1 vs 3 hourly(monthly)	<0.1	2.5	<0.1	0.4
EOF	No GEO artifacts			
GEO directional	Consistent with CERES			

- All biases are < 1% or consistent with CERES fluxes (SW SARB and Surface)

TOA global 3-year flux means

Jul02-Jun05	ERBE-like		nonGEO		GEO	
(Wm-2)	Terra	Aqua	Terra	Aqua	Terra	Aqua
OLRtot	239.0	239.6	237.7	238.1	237.2	237.9
SWtot	97.9	96.0	96.6	95.1	97.6	96.4
NETtot	4.4	5.7	7.1	8.2	6.6	7.0
OLRcs	266.5	267.8	266.6	267.3	264.3	265.5
SWcs	49.1	49.6	51.1	49.4	51.0	49.3
NETcs	25.7	24.0	23.3	24.5	26.1	25.3
OLRcf	27.5	28.2	28.9	29.2	27.2	27.6
SWcf	-48.8	-46.6	-45.5	-45.7	-46.6	-47.1
NETcf	-21.3	-18.2	-16.6	-16.5	-19.4	-19.4

• XTRK comparison FM1, FM4

TOA global 5-year flux means (Mar00-Feb05)

Wm-2	CERES ES-4 ERBE-like	CERES SRBAVG non-GEO	CERES SRBAVG GEO	SRB GEWEX	ISCCP FD	NCEP REANAL-YSIS	GEOS4
$OLR_{ALL\text{-}SKY}$	239.0	237.7	237.1	240.6	235.8	238.6	250.4
$SW_{ALL\text{-}SKY}$	98.3	96.6	97.7	101.2	105.2	117.2	92.4
$NET_{ALL\text{-}SKY}$	4.0	7.0	6.5	-2.5	0.5	-11.6	-1.0
$OLR_{CLEAR\text{-}SKY}$	266.6	266.4	264.1	268.1	262.3	270.3	271.5
$SW_{CLEAR\text{-}SKY}$	49.3	51.2	51.1	53.5	54.2	54.8	47.1
$NET_{CLEAR\text{-}SKY}$	25.4	23.7	26.2	17.7	25.0	19.1	23.1
$OLR_{CLOUD\text{-}FORCING}$	27.6	28.7	27.0	27.5	26.5	31.7	21.1
$SW_{CLOUD\text{-}FORCING}$	-49.0	-45.4	-46.6	-47.7	-51.0	-62.4	-45.3
$NET_{CLOUD\text{-}FORCING}$	-21.4	-16.7	-19.7	-20.2	-24.5	-30.7	-24.1